TECHNOLOGICAL OPTIONS

For the Treatment and Valorization of Palm Oil Mill Effluent in Indonesia

2021

WIPO GREEN
The Marketplace for Sustainable Technology

WINROCK INTERNATIONAL

PRODUCED BY

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WIPO GREEN, an initiative of the World Intellectual Property Organization (WIPO), is a public-private marketplace that promotes green technology innovation and diffusion; connects technology providers with technology seekers; and offers support to catalyze mutually beneficial commercial transactions. Its mission is to contribute to the accelerated adaptation, adoption, transfer, and deployment of green technology solutions, in both developing and developed countries.

WIPO GREEN has two major components: the WIPO GREEN Database and the WIPO GREEN Network. The WIPO GREEN database consists of inventions, technologies, know-how, and services, as well as expressed needs. Solution seekers and innovators can upload their needs and solutions to the database for potential matching, all free of charge. It is not a requirement that technologies are protected through patents or other intellectual property rights. The WIPO GREEN Network serves as a global platform that connects users, fosters partnerships, and provides a marketplace for green inventions, technologies, know-how, and services.

All identified needs and technologies for palm oil mill effluent (POME) treatment and valorization as part of the WIPO GREEN Acceleration Project 2021 in Indonesia are published on the WIPO GREEN database.

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WINROCK INTERNATIONAL

Winrock International (Winrock) is a nonprofit organization that works with people in the United States and around the world to empower the disadvantaged, increase economic opportunity, and sustain natural resources across the globe. Winrock International is a recognized leader in U.S. and international development, providing solutions to some of the world's most complex social, agricultural and environmental challenges. Winrock International implements a portfolio of over 140 agriculture, environment and social development projects in more than 46 countries.

Winrock's programs in Indonesia inform decision-making for promoting clean energy solutions (bioenergy, solar, and wind), sustainable land use, and improving the agricultural practices of smallholders. Winrock has a thorough understanding of the Indonesian palm oil sector and environmental issues through work on peat forest carbon reduction, guidelines for smallholder peatland management, and creation of two carbon accounting methodologies for peatland palm oil production in southeast Asia. Winrock has a strong reputation as a technical advisor and facilitator of POME-to-energy projects in Indonesia.

For the WIPO GREEN Acceleration Project 2021 in Indonesia, Winrock utilized its network of contacts and leadership on POME-to-energy projects in Indonesia to interact with palm oil mill owners, technology suppliers, and industry associations, and to produce the 2021 WIPO GREEN technology catalog.

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ABOUT the PROJECT

Through a partnership with the World Intellectual Property Organization (WIPO), Winrock International implemented the 2021 WIPO GREEN Acceleration Project titled Technological Options for Treatment and Valorization of Palm Oil Mill Effluent in Indonesia.

The outcome of the project is this catalog, which lists, describes, and analyzes cutting-edge technologies relevant and available for palm oil mill effluent (POME) treatment and valorization. The information in this catalog is based on data collected through interviews and questionnaires completed by palm oil mills in Indonesia, in-person and online meetings with technology providers in Indonesia and around the world, and through published company profiles, technology brochures, and websites. This catalog compiles relevant technologies, suppliers, and investment requirements to respond to a mill's needs with the goal of making it easier for mills and financiers to evaluate and pursue these options. Additionally, the technologies listed in this catalog may also be of relevance for other food processing and agriculture industries that work with high organic content and wastewater stored in lagoons (e.g. tapioca starch).

Major organizations consulted and interested in the development of this catalog include: the Directorate General of Plantations for the Indonesian Ministry of Agriculture, the Roundtable on Sustainable Palm Oil (RSPO), the Indonesian Palm Oil Association (GAPKI), the Indonesian Biogas Association (ABgI), the Resilience Development Initiative (RDI), Deutsche Gesellschaft für Internationale Zussamenarbeit (GIZ), the Sustainable Palm Oil Initiative (SPOI), the Global Green Growth Institute (GGI), and the United Nations Development Programme (UNDP) Indonesia.

MORE ON THE CATALOG

The technology catalog features six technology fields for the treatment and utilization of POME: biogas utilization, scum and sludge treatment, compost and fertilizer production, biochar production, animal feed supplements production, and green hydrogen projects. The biogas utilization technology field is further divided into four technology areas: biogas power plant systems, biogas scrubbers, biogas upgrading systems, and biogas for transportation. For each technology field and area, the catalog provides an overview of the POME involved process, a summary of the economic information, general benefits, opportunities, and challenges, as well as the greenhouse gas (GHG) emission reduction potential, where possible. Selected providers are highlighted with a summary of the technical feasibility of their technology, including the possible project implementation models. The units used in this catalog are based on the International System of Units.

The technology fields featured in this catalog were selected in response to the needs expressed by 14 palm oil mills in Indonesia during one-on-one interviews. The technology providers included in this catalog are companies that provide potential solutions to those needs, are developed and/or deployed in Indonesia, and are considered innovative ways to improve the sustainability of the palm oil industry. They were selected based on their responses to research questionnaires and participation in focus group discussions along with information obtained through personnel interviews and email correspondence. Each technology featured aims to reduce GHG emissions through the treatment of POME and some additionally demonstrate how to generate value additions from POME, such as renewable energy for replacing fossil fuel consumption, compost to replace chemical fertilizers, or other valuable byproducts.

More information, as well as contact information, on each featured provider and technology listed in this catalog, as well as additional providers and technologies not featured, can be found in the WIPO GREEN database. The WIPO GREEN database is an online platform for accelerated adaptation, adoption, and deployment of green technology solutions, linking technology seekers and service providers. Each of the technology descriptions include their WIPO GREEN database ID number at the top of the page, which can be used to locate the technology within the WIPO database. All needs and technologies identified can additionally be found in a collection on the database landing page. Further needs and technologies can be uploaded to the WIPO GREEN database.

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Build, Own, Operate, and Transfer	BOOT
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Carbon Dioxide Equivalent	CO_2eq
Crude Palm Oil	CPO
European Union	EU
Empty Fruit Bunch	EFB
Engineering, Procurement, Construction, and Commissioning	EPCC
Engineering, Procurement, and Construction	EPC
Fresh Fruit Bunch	FFB
Greenhouse Gas	GHG
Hydrogen	H_2
International Sustainability and Carbon Certification	ISCC
High-Density Polyethylene	HDPE
Indonesian Sustainable Palm Oil	ISPO
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Kilowatt Hour	kWh
Megawatt Electric	MWe
Ammonia	NH_3
Normal Cubic Meter	Nm^3
Operation and Maintenance	O&M
Palm Oil Mill Effluent	POME
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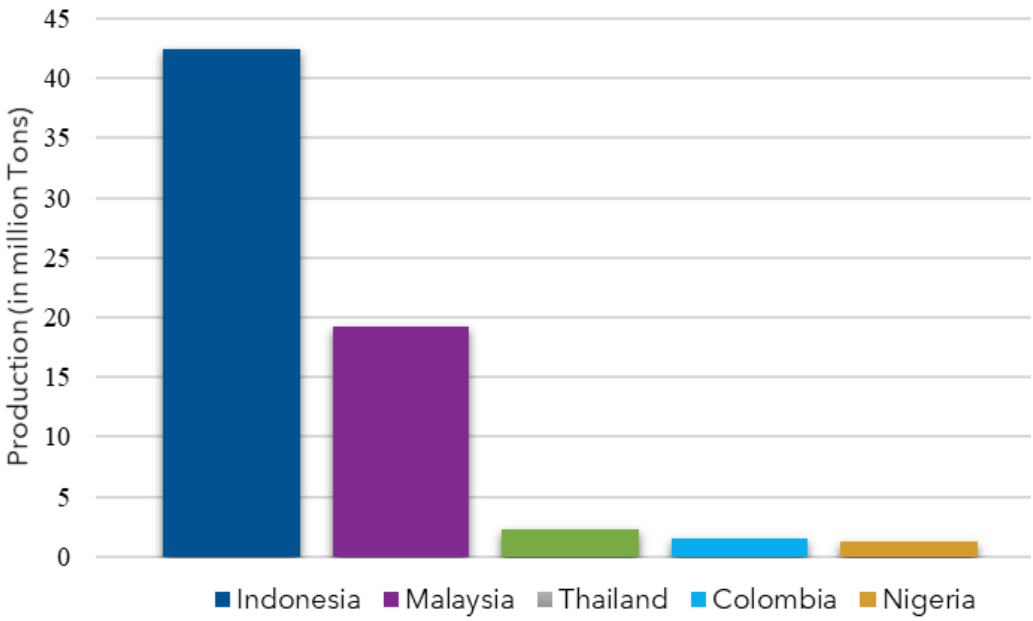
Roundtable on Sustainable Palm Oil	RSPO
Single-Cell Protein	SCP
Special Purpose Vehicle	SPV
Technology Readiness Level	TRL
World Intellectual Property Organization	WIPO

PALM OIL in INDONESIA

Palm oil is the most widely consumed vegetable oil on the planet, found in packaged products from lipsticks and shampoos, to pizza doughs and chocolates. While palm oil is accepted to be a relatively efficient source of vegetable oil, it is widely known to have a distressing carbon footprint, with the industry's rapid expansion significantly contributing to the global concentration of greenhouse gases (GHG).[1]

Plantations producing palm oil account for ten percent of global permanent cropland,[2] and over 85 percent of palm oil is produced in Indonesia and Malaysia.[3] Indonesia increased production to 42.5 million metric tons of palm oil in 2019, 58 percent of the global production.[3] Malaysia followed in second, producing 26 percent of global production at 19.3 million tons.[3]

Palm oil production for the top palm oil producing countries in 2019[3]



The next major palm oil producers include Thailand, Colombia, and Nigeria, although all three individually produced less than 3 million tons in 2019 (see figure).[3]

The Riau province in Sumatra was the largest palm oil producer in Indonesia in 2019, with 9.87 million tons of crude palm oil (CPO) produced per year, a yield of 4.13 tons of CPO per hectare.[5] Currently, the area with the highest palm oil productivity is the Central Kalimantan province with an annual yield of approximately 4.9 tons of CPO per hectare, which results in 7.4 million tons of palm oil per year.[5]

The industry has large economic implications for the country, with most of the palm oil production in Indonesia being exported to foreign countries. In 2019, Indonesia exported 30.2 million tons of palm oil, a value addition of roughly USD 16 billion dollars. The top five importing countries of palm oil from Indonesia in 2019 were India, Spain, Singapore, the Netherlands, and Malaysia, although Malaysia is likely primarily processing or re-exporting.[3] Domestically, over 2 million people in Indonesia are directly employed by the palm oil industry, with many more receiving indirect economic benefits.

PALM OIL and GHG EMISSIONS

Today, three billion people in 150 countries use products containing palm oil.[2] Between 1995 and 2015, the global production of palm oil quadrupled, from 15.2 million to 62.6 million tons per year, and by 2050 it is expected to quadruple again, reaching 240 million tons of palm oil produced in a single year. Similarly, the total land area planted with oil palm in Indonesia has more than tripled since 2000 to nearly 14.33 million hectares in 2018.[3]

The European Union's (EU) Renewable Energy Directive (RED) and Fuel Quality Directive increases demand for palm oil for biofuel while requiring that these biofuels meet specified GHG reduction thresholds. Moreover, to qualify for a certification that demonstrates equivalence with the EU requirements, many certification schemes have incorporated these GHG requirements into their own standards. The International Sustainability and Carbon Certification (ISCC) as well as the Roundtable on Sustainable Palm Oil (RSPO) standards are examples of how certifications for the palm oil industry are going above and beyond to incorporate the EU GHG requirements.[6]

Total baseline emissions of the palm oil sector in Indonesia are high, at just over 40 million tons of carbon dioxide equivalent (CO_{2eq}) per year,[7] however the country is committed to reducing its national GHG emissions. Indonesia has a target set for a 29 percent reduction compared to business as usual by 2030, or 41 percent with support from international partners as part of its Nationally Determined Contribution under the Paris Agreement. Additionally, Indonesia has set goals for increasing energy production capacity of the country by 35 GW, with 25 percent coming from renewable sources.[8]

These international and national goals and requirements, coupled with the ever growing global production of palm oil, are driving the palm oil industry to improve the sustainability of the industry and create opportunities for GHG emissions reductions. This can be done not only by improving the palm oil processing itself but as well as through the waste processing, specifically the treatment of palm oil mill effluent (POME).

POME is a thick, brown discharge generated from the processing of the palm fruit bunches, consisting of a combination of wastewater, residual oils, and solid wastes. POME volume and make-up varies by the fresh fruit bunch (FFB) condition, the processing setup and conditions, and the overall efficiency of the mill.[9] It is generally estimated that about 2.5 to 3.37 tons of POME is generated to produce a single ton of palm oil.[10]

POME is commonly treated in open ponds under anaerobic conditions, and while this treatment is simple and requires low investment and energy inputs, this system has a high area demand and results in GHG emissions estimated between 2,500 and 4,000 kg of CO_{2eq} per hectare per year, or between 625 and 1,467 kg CO_{2eq} per ton of CPO.[12] Emissions from POME itself accounts for roughly a third of the total GHG emissions from the Indonesian palm oil industry, at around 12.4 million tons of CO_{2eq} per year*.[11]

Producing this amount of GHG emissions from POME involves several different groups of microorganisms. The POME digestion process starts with bacterial hydrolysis, which breaks down the insoluble long-chain polymers of fats, proteins, and carbohydrates into short-chain polymers. Next, acidogenic acid bacteria convert the fatty acids, amino acids, and sugars into carbon dioxide (CO_2), hydrogen (H_2), ammonia (NH_3), and organic acids, which are in turn converted to acetic acid, perhaps most well-known as the main component of vinegar. This final product is then converted by methanogenic bacteria into GHGs, mostly methane (CH_4). Indicators for the quantity of gases produced include the values of both the biological oxygen demand (BOD) and the chemical oxygen demand (COD) of the POME, which point to the amount of organic matter present and accessible.[13] Under normal temperature and pressure conditions, this relationship equates to 0.35 normal cubic meters (Nm^3) of methane for every kg of COD removed.[14]

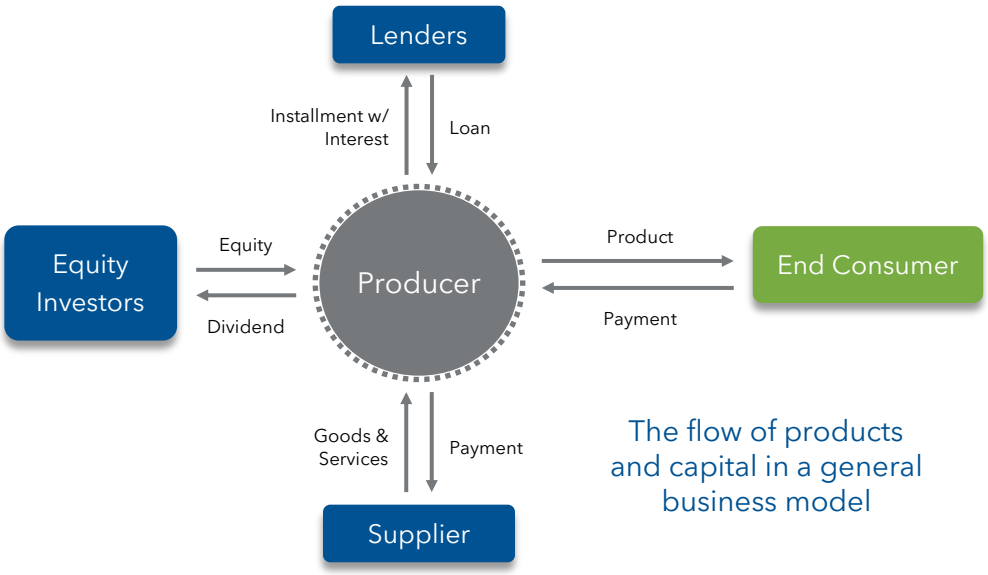
***** Assuming 900 mills with an average capacity of 45 tons fresh fruit bunch per hour, milling 10 hours per day for a minimum of 300 days per year.

Generally, best practices for managing the GHG emissions from POME include pond coverings, methane capture technology for generating biogas electricity, and the production of fertilizers from the decomposed materials. A number of new technologies are now available to provide other uses of the biogas where the market for electricity is not attractive, as well as alternative methods to process POME to produce other value additions while reducing GHG emissions.

Improved POME treatment initiatives are driven by a number of factors, including the desire of mills to access incentives, meet government requirements, comply with legal or voluntary standards, and/or to meet the demands of consumers. There are an increasing number of sustainability certification schemes, such as the ISPO and the RSPO that have established related criteria for sustainable palm oil businesses and this will continue to be a major driver for future POME treatment solutions.

PROJECT IMPLEMENTATION MODELS

A business model can influence how a project is financed and may impact profitability for the different parties involved. In a general business model, producers deliver products to an end consumer, made possible by a number of interactions between the producer and various suppliers, equity investors, and lenders.



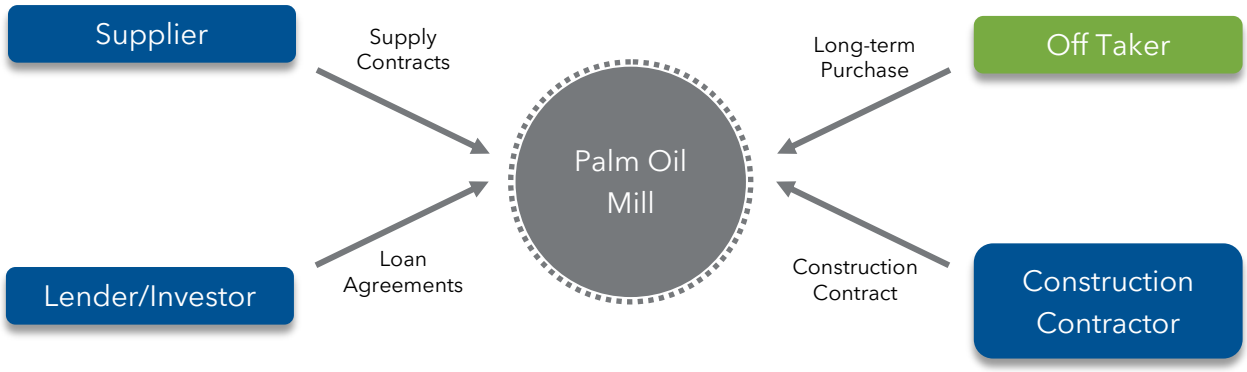
The flow of products and capital in a general business model

POME treatment projects can be implemented with various business models, with the most common in Indonesia being the build, own, and operate (BOO) and build, own, operate, and transfer (BOOT). A Public Private Partnership (PPP) model is a prospective model for future projects involving the government.

BUILD, OWN, and OPERATE (BOO) MODEL

Under the BOO model, the palm oil mill owner builds the facility and operates it as part of its regular mill operations. The model may involve external parties such as investors, engineering, procurement, and construction (EPC) contractors, or project operators, but the overall responsibility and ownership belongs to the mill. In this model, the owner has full control over the project.

In one variation of the BOO model, the mill engages a business cooperation with a third-party developer and establishes a special purpose vehicle (SPV) to run the project. In this arrangement, the mill acts as a minor shareholder, while the third-party acts as a major shareholder and manages the overall project. The following is an adapted diagram of the BOO business model.[15]

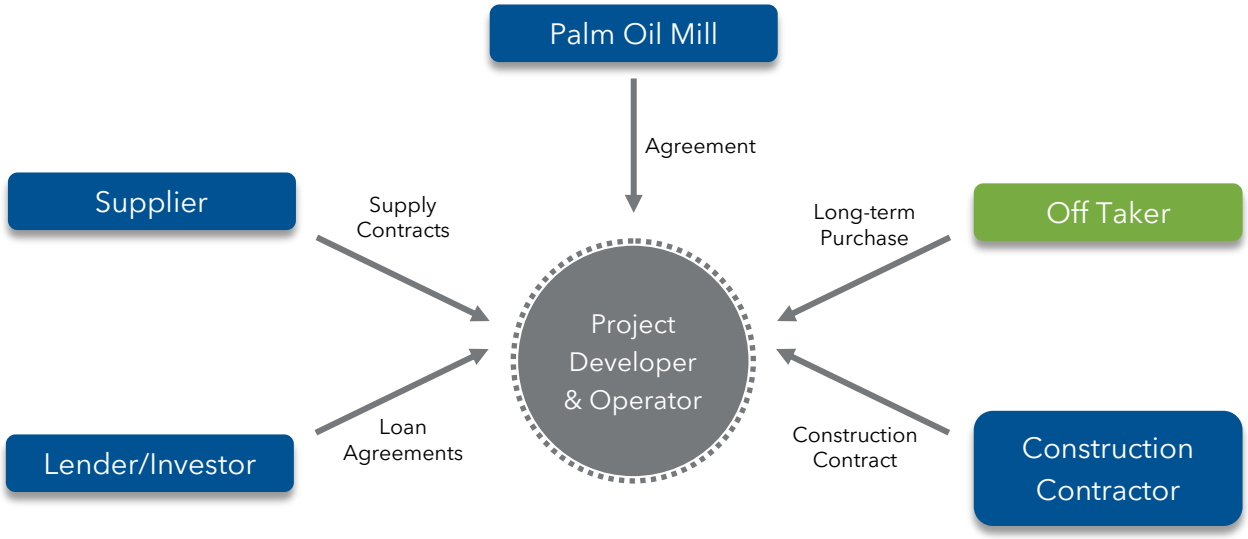


Adapted BOO business model for a palm oil mill in Indonesia[15]

BUILD, OWN, OPERATE, and TRANSFER (BOOT) MODEL

In the BOOT model, a project developer, a private party, or a consortium receives a mandate from the palm oil mill to finance, design, construct, own, and operate a facility, typically for a long-term period, generally 15 to 20 years.[16] During this period, the project developer owns and operates the facility with the goal of recovering the costs of investment, operations, and maintenance while trying to achieve an appropriate margin for the project. At the end of the specified period, ownership of the facility is transferred back to the mill.

The BOOT model offers the possibility of realizing a project where the efficiency and competency of the project developer and its economic interest in the project will produce cost efficiencies to the mill when the agreement period ends. However, the project owner must consider the complicated structure, which requires detailed planning, time, and budgeting throughout the concession period.[15] Below is an adapted diagram of the BOOT business model.[15]

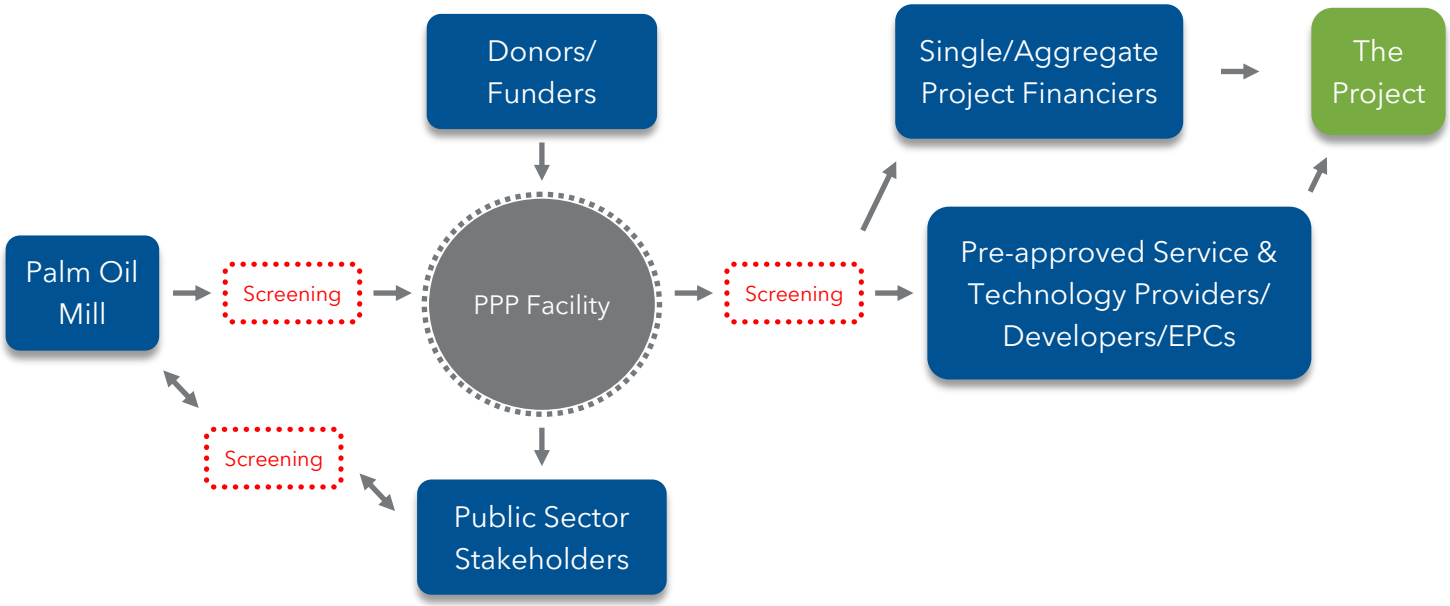


Adapted BOOT business model for a palm oil mill in Indonesia[15]

PUBLIC PRIVATE PARTNERSHIP (PPP) MODEL

A PPP is a service contract between the public and the private sector where the government pays the private sector to deliver facility and related services over a long-term period. Private sector parties who build the public facility are financially responsible for its condition and performance throughout the asset's lifetime. PPP structures may vary in terms of service management and control of assets, where it can be public dominant or private dominant or mixed.

In a typical PPP project, the government would engage one party, usually a consortium of private businesses that come together to form a SPV, to design, finance, construct, maintain, and, in some cases, operate the facility. The government would make payments only after the facility has commenced operations and would provide payments over the term of the contract based on services delivered against the achievement of key performance indicators, with these payments being at risk for no-performance.[17] The following is an adapted diagram of the PPP business model.[6]



Adapted PPP business model for a palm oil mill in Indonesia.[15]

Generally, PPP is perceived to provide an efficient solution, providing transparency, improved performance and new sources of funding. A lot of preparation and development funding could be required to de-risk individual projects, as well as the broader POME utilization asset class, by accelerating the funding, construction, and successful operation of the projects. The PPP typically; screens the mills, technology and service providers, and developers; conducts pre-financing and other early-stage project preparation services such as feasibility studies; coordinates with an off takers to identify the most viable projects; and supports uncertainties in the project financing deals by building trust and knowledge, conducting first-round activities and bringing together project stakeholders to advance the most promising project structures. The establishment of the PPP facility will require early partnership with the government of Indonesia and development funders that are driven to implement the projects to meet Indonesia's energy, environmental, and/or economic goals. These entities will help establish buy-in from government counterparts and facilitate completion of administrative and legal requirements for establishing the facility.

POTENTIAL FUNDERS and CARBON MARKETS

POTENTIAL FUNDERS

Those in the palm oil industry that need additional resources to finance POME projects can look to financial institutions or funders to facilitate that liquidity as equity investors or as loan providers. The following are examples of prospective funders for POME processing and valorization projects in Indonesia, many of which have a record of supporting climate friendly business.

COMPANY/ORGANIZATION	WEBSITE
PT. Indonesia Infrastructure Finance (IIF)	iif.co.id
PT. Sarana Multi Infrastruktur (SMI)	ptsmi.co.id
Bank Mandiri	bankmandiri.co.id
Bank BNI	bni.co.id
Bank BRI	bri.co.id
Bank BCA	bca.co.id
Bank Sumsel Babel	banksumselbabel.com
Tropical Landscapes Finance Facility (TLFF)	tlffindonesia.org
Indonesia Climate Change Trust Fund (ICCTF)	icctf.or.id

VOLUNTARY CARBON MARKETS

Carbon offsetting refers to the reduction or sequestering of one metric ton of carbon dioxide emissions, or equivalent, by an entity to compensate for emitting that metric ton elsewhere. Global carbon offset demands have triggered some companies to trade carbon credits, a generic term for any tradable certificate or permit representing the right to emit one metric ton of carbon dioxide or equivalent. This motivates more businesses to invest in voluntary offsetting. POME treatment and valorization projects contribute to GHG emissions reductions and, those accredited based on international standards, may generate income from voluntary carbon credit markets. In the adjacent list are some global service providers in the voluntary carbon market.

COMPANY/ORGANIZATION	WEBSITE
ACT	actsustainability.com
ALLCOT	allcot.com
Arbor Day Foundation	arborday.org
bp Target Neutral	bp.com/en_gb/target-neutral/home
Carbonsink	carbonsink.it
Climate Neutral Group	climateneutralgroup.com
ClimateCare	climatecare.org
CO2balance	co2balance.com
EcoAct	eco-act.com
First Climate	firstclimate.com
Mirova Natural Capital	mirova.com
Natural Capital Partners	naturalcapitalpartners.com
South Pole	southpole.com
Toitū Envirocare	toitu.co.nz
Vertis	vertis.com
VNV Advisory	vnvadvisory.com
3Degrees	3degreesinc.com

The TECHNOLOGY CATALOG

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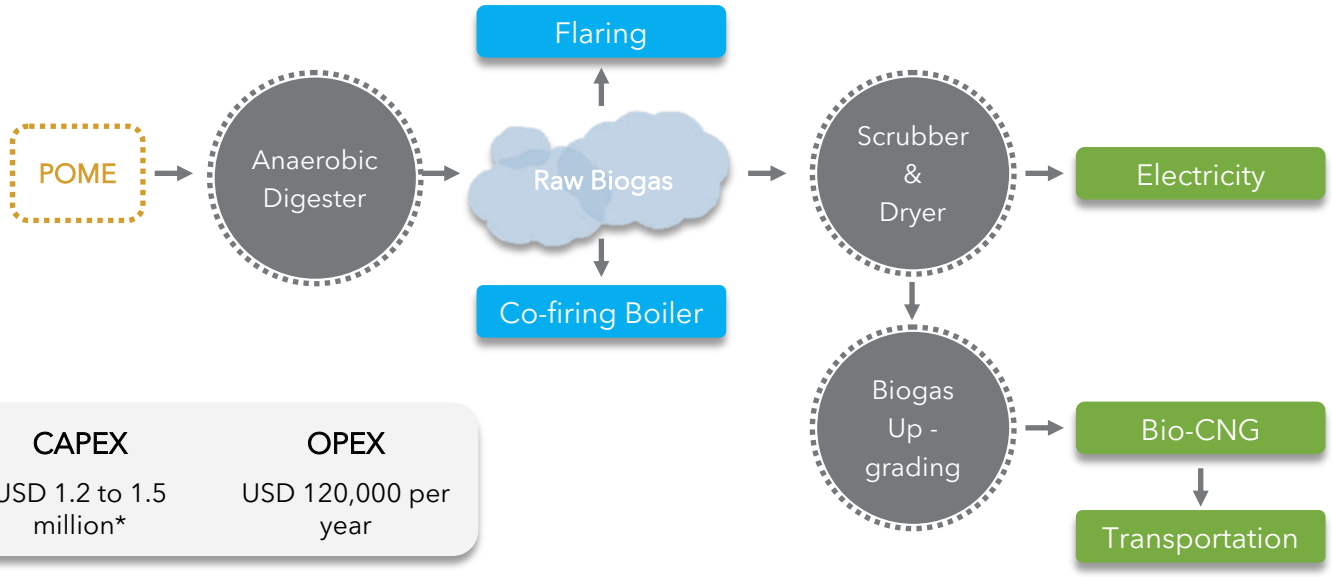
FEATURED PROVIDERS and TECHNOLOGIES

The following are prerequisites and potential outcomes for implementation of the featured technology options, where possible to determine. This information can be used to estimate project viability and attractiveness.

	PREREQUISITES	POTENTIAL
Biogas Power Plant Systems	Minimum capacity of 1 megawatt electric (MWe) if the project is developed by mill, 2 MWe if the project is developed by project developer	A 60 tons fresh fruit bunch (FFB) per hour mill can produce 900-1,200 normal cubic meters per hour (Nm^3/h) of biogas and generate up to 2-3 MWe of electricity
Biogas for Transportation *(Bio-CNG)*	Minimum capacity of 45 tons FFB per hour if the project is developed by mill, 60 tons FFB per hour mill if the project is developed by project developer	A 60 tons FFB per hour mill can produce 900-1,200 Nm^3/h biogas and produce approximately 500-700 diesel liter equivalent per hour Bio-CNG (biogas-based compressed natural gas)
Scum & Sludge Treatment	No minimum size of the mill	7,000-9,000 tons dry solid is expected to be produced annually from a 60 tons FFB per hour mill
Compost Production	No minimum size of the mill	34,500 tons compost is expected to be produced annually from a 60 tons FFB per hour mill. The estimated area covered is 1,700 ha
Fertilizer Production	At least 45 tons FFB per hour mill to be feasible	37,800 tons organic fertilizer is expected to be produced annually from a 60 tons FFB per hour mill
Biochar Production *Small scale*	Furnace is available for 50 kg empty fruit bunch (EFB) and 500 kg EFB	12.5 kg biochar is produced from 50 kg of EFB. 125 kg of biochar is produced from 500 kg of EFB
Biochar Production *Industrial scale*	N/A	14,400 tons biochar is expected produced annually from 60 tons FFB per hour mill
Animal Feed Supplements *iCell*	At least developed in 45 tons FFB per hour mill to produce 1,000 tons SCP per year	1,000 tons of SCP is produced annually from 45 tons FFB per hour mill
Green Hydrogen Projects *HDF*	Depends on size and context	

BIOGAS ULTILIZATION



CAPEX	OPEX
USD 1.2 to 1.5 million*	USD 120,000 per year

Biogas is the mixture of methane, carbon dioxide, hydrogen sulfide, and small traces of other gases. It is commonly produced anaerobically – by the breakdown of organic matter in the absence of oxygen. Biogas generally can be generated from raw materials such as agricultural waste, livestock manure, municipal waste, plant material, sewage, green waste, and food waste, as well as from POME.

Biogas digesters capture the methane, a potent GHG, that would otherwise be released into the atmosphere from the open lagoons POME is commonly stored in using various technologies ranging in cost and complexity. The captured methane, can be utilized as a renewable energy source to replace fossil fuels, to generate electricity, and to use as boiler fuel. Each cubic meter of POME** releases 25.6 Nm^3 of biogas, with each normal cubic meter of biogas carrying the potential to generate approximately 2.1 kWh of electricity.[15]

510 kg CO_{2eq}
per ton CPO

Estimated GHG reduction potential by capturing biogas[18]

OPPORTUNITIES

- Reducing GHG emissions
- Generating on-site renewable and reliable energy source
- Transforming organic wastes into high value products
- Improving local access to energy through reliable electricity
- Reducing soil and water pollution

***** Biogas for co-firing boiler, 500 to 750 Nm^3/hour
****** With a raw COD of ~55,000 mg/l, 80 percent COD removal and 55 percent methane content.

OTHER BENEFITS

- By-products can be used as fertilizer
- Minimizes odor and quantity of POME sludge
- Reduces quantity and volume of post-treatment ponds
- Accelerates COD reduction

CHALLENGES

- Energy generation is influenced directly by COD level and POME flow rate, which can be inconsistent
- Insufficient environment controls and fluctuating loading of the organic substrate
- Methane-producing bacteria, methanogens, have specific parameters (i.e. temperature and pH)

32,000 tons CO_{2eq}
per year
Potential GHG emissions reductions from methane capture of a 60 tons FFB/hour mill[19]

PRODUCING BIOGAS from POME

Anaerobic digestion is the primary method for producing biogas from POME, where modern digester designs are capable of producing high biogas yields and maintaining stable outputs. Biogas produced from biogas digester can be utilized in several applications, such as for power generation using a biogas engine, for co-firing boilers, and for flaring. This technology has the potential to reduce a significant amount of the GHG emissions, compared to the commonly used open lagoon system. In anaerobic systems, most of the biodegradable organic matter present in the waste is converted into biogas, which is piped out of the reactor. Only a small portion, about 5 to 15 percent, of the organic material is converted into microbial biomass, which then forms the excess sludge of a system.[19] Depending on wastewater characteristics, the material not converted into biogas or microbial biomass, about 10 to 30 percent, leaves the reactor as non-degraded material that is high in nitrogen and can be used as fertilizer and compost for crops and soils.[19]

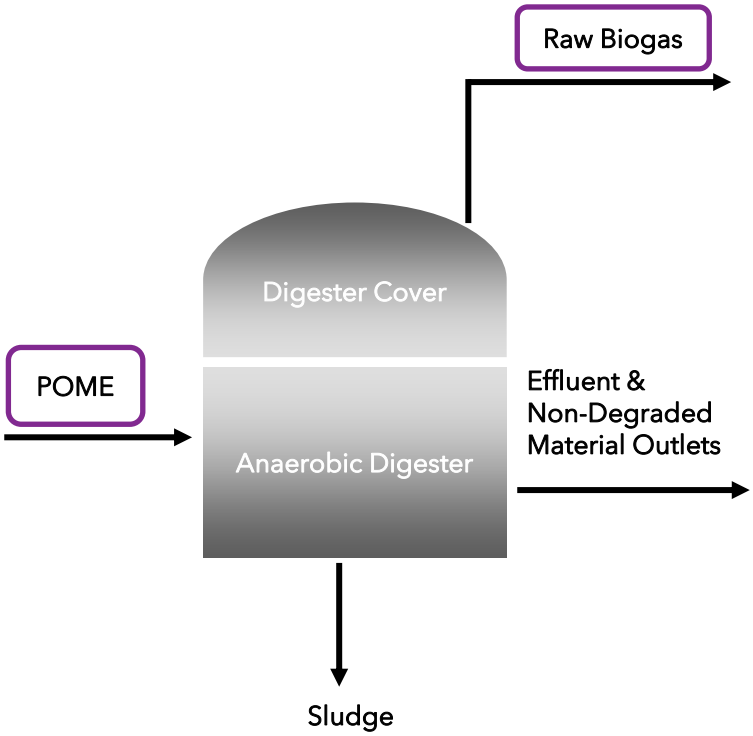


Image: Anaerobic digester (Source–The Irish Times).

BIOGAS POWER PLANT SYSTEMS

CAPEX

USD 2 to 2.5 million per MWe

OPEX

5 to 9 percent of EPC costs

OPPORTUNITIES

- Replacing fossil fuel
- Reducing cost of energy (thermal or electricity)
- Reducing GHG emissions
- Producing a renewable fuel for boilers
- Accelerating decomposition of POME

CHALLENGES

- Energy generation is influenced directly by COD level and POME flow rate, which can be inconsistent
- High initial investment costs
- Financial viability depends on attractive prices for the generated power and a ready market for the raw biogas
- Requires stable regulation with an attractive feed-in-tariff and a fixed permit processing timeline
- The mill and the electricity interconnection point must be in close proximity

Biogas power plants produce biogas from POME and convert it into fuel and electricity, offering an alternative to fossil fuel consumption and a reduction of the contribution by POME processing to GHG emissions. The combination of heat and electricity produced can be used for a mill's own consumption, which can reduce spending, as well as be used to generate extra income through selling the electricity to a national grid. In addition, the biogas generated from these power plants can be used for on-site flaring to further reduce GHG emissions. The biogas used for co-firing a boiler can give additional income for the mill, and the shells saved can be directly sold.

Images: (Upper) PTPN V biogas co-firing boiler plant (Source–PT. Ecody Agro Energi). (Lower) Semilar biogas power plant (Source–PT. Karya Mas Energi).

2.6M tons CO_{2eq}

per year

Reduction in GHG emissions if 100 mills produced biogas from POME[19]

WIPO ID | 23662

BPO

BPO designs POME biogas digesters with a long-term reputation of operational reliability. BPO's CH_4 Generating Reactor is a stable and efficient anaerobic in-ground system ideal for biogas production. The sludge management and feed distribution networks prevent sludge accumulation while ensuring optimum digestion.

COLLABORATION TYPE For Sale

DEVELOPED IN New Zealand

PREFERRED REGION Indonesia, Southeast Asia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

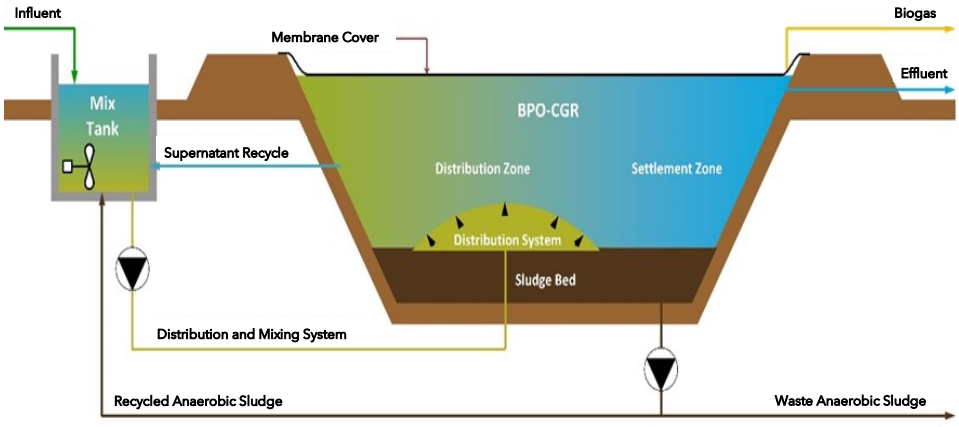
ADVANTAGES

- Custom/fit-for-purpose projects
- Removes > 90 percent of COD and BOD
- Built-in equalization for any downstream aerobic system

SERVICES OFFERED by BPO

- Design/build solutions
- Process design and detailed engineering
- Wastewater testing
- Pilot studies
- System commissioning
- Operator training

BPO-CH_4 Generating Reactor Schematic Process



WIPO ID | 23713

PT. Organics Bali

Organics Bali designs and builds anaerobic digestion systems capable of producing biogas from a variety of waste streams. The goal of their power plant systems is to leverage biogas production to treat the high levels of COD found in POME and ensure that the contribution of the methane gas produced to climate change is reduced.

COLLABORATION TYPE For Sale

DEVELOPED IN United Kingdom

PREFERRED REGION Southeast Asia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

Image: Biogas plant at Sinarmas, Central Kalimantan (Source–Organics Bali).

SERVICES OFFERED by PT. Organics Bali

- Design
- Installation
- Commissioning

ADVANTAGES

- Corrosion resistant
- Improved cover design with emphasis on safety
- Compact, integrated design of influent pumping station
- Long hydraulic and solids retention time
- High process stability after shock loading
- Uses durable and UV stabilized materials

WIPO ID | 23710

PT. Elmoz Geo Solusi

Elmoz is an Indonesian company with project experience in biogas power plant projects, as well as projects related to high-density polyethylene (HDPE), soil improvement, and electrical and instrumentation works. Elmoz provides biogas power plant services for palm oil, tapioca, and manure mills. Elmoz can also provide any optional wastewater development for any utilization and based on the customers budget.

COLLABORATION TYPE For Sale, Joint Venture

DEVELOPED IN Indonesia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

Image: Biogas power plant at PT. Swadaya Multi Prakarsa (Source—PT. Elmoz Geo Solusi).

ADVANTAGES

- Can be directly used as a replacement fuel for burners or for generating electricity
- Treated bio-digester effluent can be used as fertilizer
- Reduces waste pollutants to the environment, specifically waterways
- Can provide long-term investment profits

SERVICES OFFERED
by PT. Elmoz Geo Solusi

- Fabrication and installation of geosynthetic, piping and fitting HDPE
- Soil test
- Earthwork
- Civil constructions
- Mechanical and electrical maintenance
- Electrical and instrument installation
- EPCC
- Process guarantee

WIPO ID | 105502

PT. Karya Mas Energi

Karya Mas Energi develops projects with the intention of converting on-site palm oil waste into a source of energy and to date have developed eight methane capture projects for electricity generation and co-firing boilers. The generated electricity is distributed to a palm kernel crushing plant or to be sold to the national power grid under a power purchase agreement (PPA). The heat for the boiler reduces a significant amount of palm shell previously used as fuel.

One of Karya Mas Energi's projects, the Tandun biogas power plant, has been listed as a project eligible to be certified in emission reduction under the clean development mechanism of the Kyoto Protocol. Their other projects, the Semilar and Perdana biogas power plants, have received the International Sustainability and Carbon Certification.

COLLABORATION TYPE For Sale, Joint Venture

DEVELOPED IN Indonesia

PREFERRED REGION Indonesia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

ADVANTAGES

- Experienced in PPA schemes and projects combined with a co-firing boiler

SERVICES OFFERED
by PT. Karya Mas Energi

- Design, construction, operation, and service
- Waste audit
- Energy audit
- Feasibility study
- EPCC for PPA scheme
- Project development

WIPO ID | 23706

PT. Ecody Agro Energi

Ecody's biogas technology is used to convert organic waste into biogas. The system in general consists of three parts:

1. *Pre-treatment System*: the fresh liquid waste is adjusted to meet the parameter required before being fed to the anaerobic reactor or digester.
2. *Digester System*: can be a covered lagoon or tank. The biogas produced is collected under the membrane cover and the treated effluent is led to a settling pond for further separation between solid and liquid.
3. *Biogas Management and Utilization*: typically consists of the H_2S scrubber and dehumidifier. An upgrading system can be added to further purify the biogas into biomethane or Bio-CNG.

COLLABORATION TYPE	For Sale, R & D Contract or Research Collaboration
DEVELOPED IN	Indonesia
READINESS LEVEL (TRL)	Scaling Up (TRL 9)

ADVANTAGES

- Capable of developing projects using PPA scheme
- Improves effluent water quality
- Wastes can be applied to land

SERVICES OFFERED

by PT. Ecody Agro Energi

- Feasibility and grid interconnection studies
- Design, EPCC
- Operation and maintenance (O&M) contract
- After sale technical assistance or consultancy service

Image: PTPN V biogas co-firing boiler plant under construction (Source—PT. Ecody Agro Energi).

WIPO ID | 23712

PT. GREE Services Indonesia

GREE designs and provides biogas-to-energy solutions that not only treat industrial wastewater and reduce GHG emissions but also turn these environmental liabilities into clean energy, organic fertilizers, and other commodities for rural communities. GREE's main expertise is developing their in-ground anaerobic lagoon digester, which is technologically mature and proven in tropical countries such as the South East Asia region.

COLLABORATION TYPE	For Sale, For Service, Joint Venture, Join development
DEPLOYED IN	Indonesia
PREFERRED REGION	Indonesia
READINESS LEVEL (TRL)	Scaling Up (TRL 9)

Image: Hamparan biogas power plant (Source—PT. GREE Services Indonesia).

ADVANTAGES

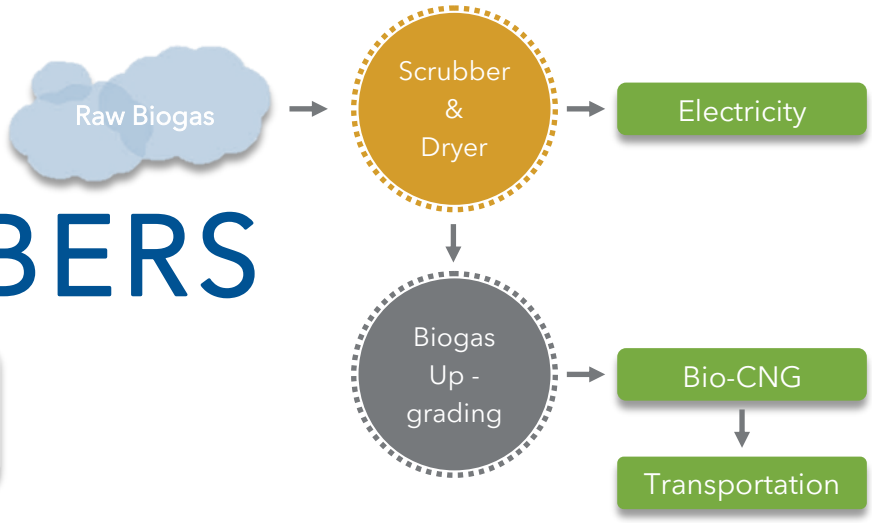
- GREE technology removes more than 90 percent of the pollutant load in industrial wastewater

SERVICES OFFERED

by PT. GREE Services

- Project development
- EPC and maintenance
- Carbon management
- O&M
- Consultancy services

BIOGAS SCRUBBERS



CAPEX	OPEX
USD 200 to 400 per Nm^3 biogas/h	USD 2,500 to 5,000 per year

A biogas scrubber is needed as part of the biogas power plant system when the biogas is to be converted to electricity through powering biogas engines. Biogas scrubbers reduce the hydrogen sulfide (H_2S) content to prevent corrosion problems in the engines and to reduce air pollution caused by sulfur oxides in the exhaust gas.[20] A biogas scrubber must reduce the H_2S concentration to permissible levels, typically below 200 parts per million (ppm). This optimizes operation and lengthens the lifetime of the biogas engines.

There are three kinds of biogas scrubbers; biological, chemical, and water. A biological scrubber uses special sulfur-oxidizing bacteria to convert H_2S to sulfate (SO_4) and is usually used for POME applications due to its low operating costs.[15]

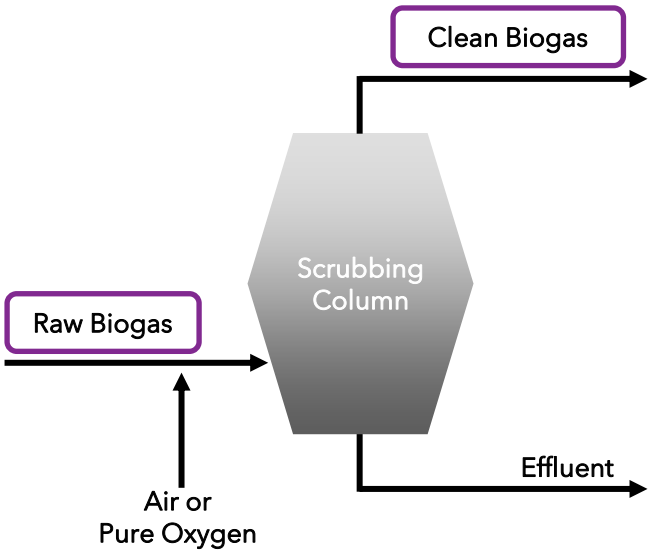


Image: Biogas column scrubber (Source–biogasclean.com).

OPPORTUNITIES

- Producing clean biogas for gas engines and biogas-upgrading
- Profiting from the sale of generated electricity and waste biomass
- Earning Carbon Credits
- Saving on diesel costs

CHALLENGES

- High quality scrubbers come with high prices

WIPO ID | 105503

Biological Scrubber

BPO

BPO supplies a full range of biological H_2S removal systems. The gas cleaners, with double epoxy and HDPE lined steel reinforced concrete tanks, are ideally suited to conditions in remote regions. Biogas with up to 10,000 ppm of H_2S enters the scrubber and sulfur oxidizing bacteria absorb the H_2S, producing elemental sulfur and sulfuric acid. Biogas leaving the scrubber ranges from 0 to 200 ppm H_2S, depending on configuration. Each BPO H_2S biogas scrubber is designed to produce specific biogas flow and H_2S loads.

COLLABORATION TYPE	For Sale
DEVELOPED IN	New Zealand
PREFERRED REGION	Indonesia
READINESS LEVEL (TRL)	Scaling Up (TRL 9)

ADVANTAGES

- Easy to construct on site using local labor
- Requires only water and a small amount of air to operate
- Simple automated operation
- Designed to withstand down to -20 millibar with pressure protection interlocks standard
- Rapid bacterial colonization, reducing commissioning timeframes to days
- Optional automatic operational and interactive graphical control
- Continual analysis of the quality of the biogas provided in real time data

Image: BPO H_2S biogas scrubber at PT. Harapan Sawit Lestari (Source–BPO).

WIPO ID | 23708

Biological Scrubber

PT. Elmoz Geo Solusi

Elmoz designs their biological scrubber to reduce the H_2S content from up to 3000 ppm to below 200 ppm with a maximum flow of 750 Nm^3 biogas per hour per scrubber unit. The Elmoz scrubber is produced and packaged in a warehouse, offering quick install of the system on site.

COLLABORATION TYPE	For Sale
DEVELOPED IN	Indonesia
READINESS LEVEL (TRL)	Early Commercial Demonstration, Adoption, Dissemination (TRL 8)

Image: Elmoz biogas biological scrubber installed at PT. Pasadena Biofuel Mandiri (Source–PT. Elmoz Geo Solusi).

ADVANTAGES

- High efficiency
- Easy O&M
- Performance guarantee

SERVICES OFFERED

by PT. Elmoz Geo Solusi

- Design and engineering
- Product supply
- Installation and commissioning
- Supervision

WIPO ID | 138631

Biological Scrubber

Biogasclean A/S

Biogasclean, a Danish privately owned corporation, specializes in developing, manufacturing, and supplying fully automated gas cleaning systems for H_2S removal, with the goal of combining affordability with high availability. Biogasclean's H_2S removal process is 100 percent biological and does not require frequent media replacements, such as iron sponge, activated carbon, etc. The only residue from the process is a valuable liquid fertilizer. Biogasclean's distributor in Indonesia is PT. Prima Flo Manunggal.

COLLABORATION TYPE For Sale, Joint Venture

DEVELOPED IN Denmark

PREFERRED REGION Global

READINESS LEVEL (TRL) Scaling Up (TRL 9)

ADVANTAGES

- Automatic air injection control system
- No chemicals and has low electrical consumption
- Performance guarantees on all projects

Image: Biogasclean biogas scrubbing column (Source–Biogasclean).

WIPO ID | 138648

Biological Scrubber

PT. Organics Bali

Organics Bali designs and manufactures vertical and horizontal biological scrubbers that can reduce the hydrogen sulfide content of raw biogas to 100 ppm. The bacteria involved in the process is ubiquitous and functions reliably and predictably under correct environmental conditions. This system is for biogas-producing projects that rely on anaerobic digestion or biogas generated in landfill sites.

COLLABORATION TYPE For Sale

DEVELOPED IN Indonesia

PREFERRED REGION Indonesia, Southeast Asia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

ADVANTAGES

- In most circumstances, no additional costs for chemical additions
- Suitable for remote location
- Operational simplicity
- Manual or automatic cleaning options available

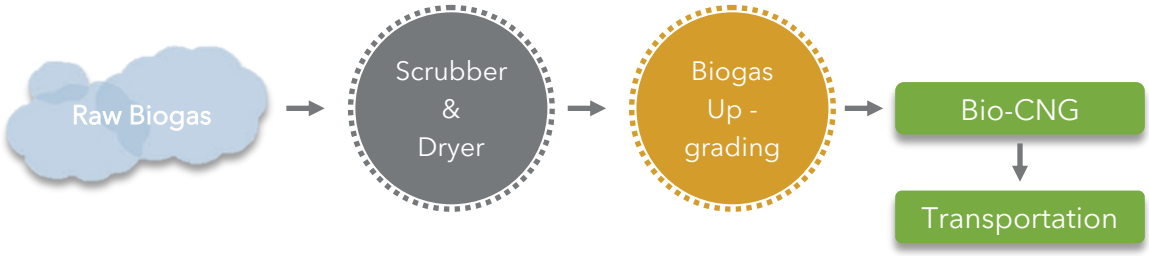
SERVICES OFFERED

by PT. Organics Bali

- Design
- Installation
- Commissioning

Image: Organics Bali bio-scrubber installation (Source–PT. Organics Bali).

BIOGAS UPGRADING SYSTEMS



CAPEX

USD 1 to 1.5 million for 500 Nm^3 biogas per hour

OPEX

USD 60,000 to 70,000 per year

The processing of biogas to natural gas quality—known as biogas upgrading—is an important prerequisite for efficient energy provisioning from biogas generated from POME.

OPPORTUNITIES

- Low overall O&M costs
- Improving air quality by replacing diesel fuel
- Generating a fuel alternative for on-site vehicles

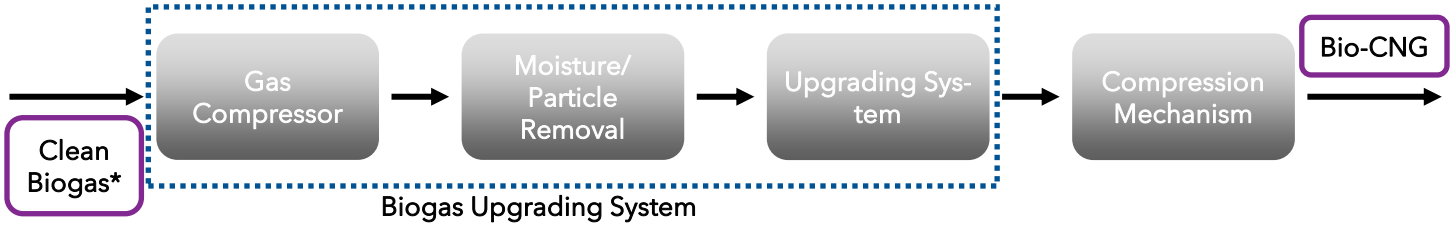
CHALLENGES

- Limited technology providers
- High installation costs

After the raw biogas from the plant has been scrubbed of its hydrogen sulfide content, the process of biogas upgrading recovers the remaining carbon dioxide (CO_2) and methane (CH_4) gases from the mixture, which can be used to replace fossil fuel consumption. Processing biogas in this way allows it to be cooled, transported, and injected into an existing natural gas network. This makes the biogas suitable for a wide range of uses including:

- In highly efficient, decentralized, combined heat and power units
- As fuel in the form of compressed natural gas (CNG) and liquefied natural gas (LNG)
- For the generation of heat
- As a raw material in the chemical industry

Commercially, the CH_4 and CO_2 gases are removed via pressure and vacuum swing adsorption, pressurized water scrubbers, amine scrubbing, scrubbing with organic solvents, membrane permeation, or physical and chemical CO_2 adsorption.[20]



* 55 to 60 percent of CH_4, and <15 ppm of H_2S

WIPO ID | 23735

Pressure Swing Adsorption

Carbotech Gas Systems GmbH

The pressure swing adsorption (PSA) process developed and patented by Carbotech is simple and has low energy requirements. The PSA technology has undergone on-going development over the past three decades resulting in an efficient processing technique: a dry process characterized by the deployment of minimal operating resources, with low electrical power requirements and no thermal power requirement. Additionally, this technology does not generate wastewater, toxic chemicals, or other contaminated wastes.

COLLABORATION TYPE For Sale

DEVELOPED IN Germany

READINESS LEVEL (TRL) Scaling Up (TRL 9)

ADVANTAGES

- Low input demands
- Simple, clean outputs
- High methane yields
- Programmable logic control and online gas analysis

SERVICES OFFERED

by Carbotech Gas Systems

- Design and product supply
- Installation/supervision/ commissioning
- Troubleshooting
- Maintenance and service

Image: CarboTech biogas upgrading plant in Sofielund, Sweden (Source–Carbotech).

WIPO ID | 23711

SEPURAN® Green

Evonik (SEA) Pte Ltd.

Evonik's membrane upgrading process with SEPURAN® Green delivers constant, high grade biomethane. The SEPURAN® Green membranes have high CO_2/CH_4 selectivity, making it possible to obtain methane from biogas with a purity level of up to 99 percent with just one compressor.

This technology has obtained the patent of 3-stage membrane-based gas separation process No. EP 2 588 217 B1, EP 2996794 B1, and EP 3240620 A1 are granted in the US and other countries.

COLLABORATION TYPE For Sale

DEVELOPED IN Germany

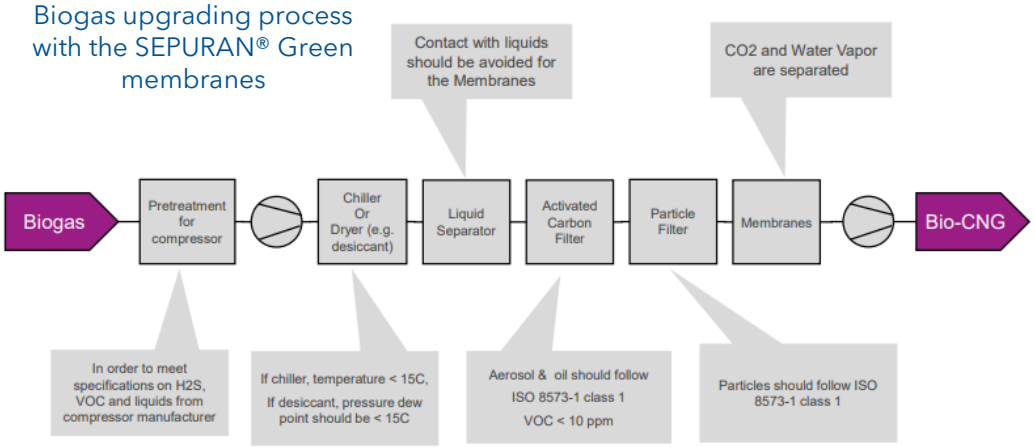
PREFERRED REGION Global

READINESS LEVEL (TRL) Scaling Up (TRL 9)

ADVANTAGES

- Almost all the methane recovered is bio-natural gas quality
- Relatively simple installation and operation
- Low space requirement and short installation times

Biogas upgrading process with the SEPURAN® Green membranes



WIPO ID | 138647

Biogas Upgrading & Distribution

Safe S.p.A.

Safe S.p.A. is an Italian based company with more than 45 years of experience in natural gas compressors and equipment manufacturing, over 10 years of which has been spent developing and supplying integrated solutions and equipment for biogas upgrading and distribution. Safe provides turnkey solutions for biogas upgrading and distribution at low, medium, and high pressures for either grid injection, bulk transportation, or natural gas vehicle filling. Their technology has integrated safety features, including electric, electro-mechanic, and mechanical monitoring devices as well as fire and gas detection.

COLLABORATION TYPE For Sale

DEVELOPED IN Italy

PREFERRED REGION Indonesia, Southeast Asia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

Image: Biogas upgrading and compression skid system (Source–Safe S.p.A).

ADVANTAGES

- Automated operation with capacity control
- Supervisory control and data acquisition and remote connectivity
- Scalable modular design
- Turnkey supply of equipment possible

SERVICES OFFERED

by Safe S.p.A.

- Design & engineering
- Product supply
- Installation
- After-sales support

BIOGAS for TRANSPORTATION

OPPORTUNITIES

- Replacing fossil fuels
- Reducing cost of fuel
- Reducing GHG and particulate matter emissions
- Reducing quantity of solid wastes in landfills

CHALLENGES

- Global markets for Bio-CNG not yet well developed
- Refueling stations are more complicated than conventional since high pressure is required
- Transportation from remote mills can require additional logistics
- Coverage area of Bio-CNG is limited by the distribution costs

Compressed natural gas (CNG) is an alternative to conventional transportation fuels and is known for its relatively low GHG emissions.[21] CNG produced from biogas—called Bio-CNG—is a colorless, odorless, and non-toxic clean fuel similar to traditional CNG in terms of composition and properties, including energy content.[22] Bio-CNG not only can be used on-site for energy generation and as vehicle fuel in mills and on plantation complexes but it can also be transported to other potential user sites or injected into a gas pipeline for industrial processes. As a result, Bio-CNG has the potential to partially satisfy a growing energy demand and reduce overall fuel costs, among other benefits.

To produce Bio-CNG, POME is subjected to three main processes:[22]

1. *Pre-treatment (H_2S scrubbing and water removal):* Raw biogas is treated using biological and/or chemical H_2S biogas scrubbers to reduce the H_2S level to less than 15 ppm (see *Biogas Scrubbers*).
2. *Purification and upgrading (CO_2 removal and CH_4 enrichment):* The pre-treated biogas is compressed to enrich the methane content to a quality similar to natural gas (see *Biogas Upgrading Systems*).
3. *Gas compression and storage:* The purified and enriched biogas is then further compressed to 250 bar and temporarily stored in cylinders or directly dispensed into a CNG trailer for transport.

Image: Bio-CNG storage and filling station facility (Source—RRS Group).

WIPO | 101325

WIPO ID | 105501

Bio-CNG Project Developer

Raja Rafa Samudra (RRS) Group

RRS is a company serving the downstream gas sector business in Indonesia. For Bio-CNG projects, the sub-group Raja Gas Kharisma (RGK) provides full-service development of the entire value chain for the production and processing of biogas, biomethane, and Bio-CNG. The company developed the first Bio-CNG plant in Indonesia and continues to apply and commercializes biogas upgrading and Bio-CNG technology to substitute diesel fuel for trucks and electric generators.

ADVANTAGES

- Has extensive experience in CNG business

SERVICES OFFERED by RGK

- Feasibility study
- Project development
- Bio-CNG utilization

Bio-CNG Powered Vehicle Fuel Conversion

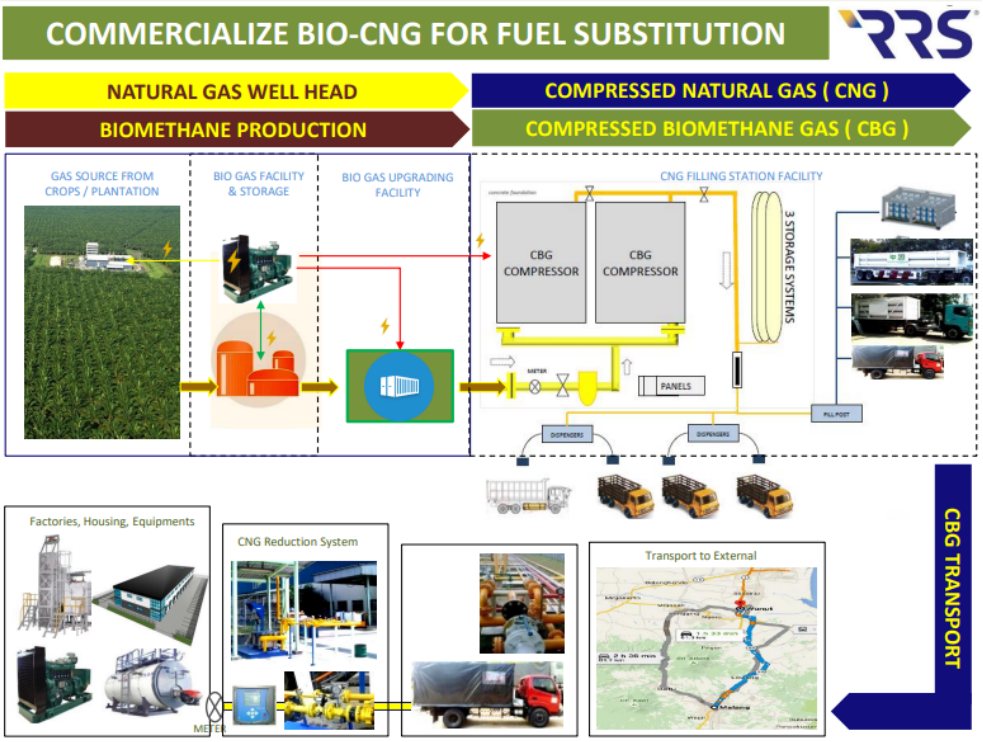
Raja Rafa Samudra (RRS) Group

Raja Gas Samudra (RGS), part of RRS Group, focuses on the gas conversion business. Adapted from European based technologies and engineering from Thailand, RGS has fully localized its installation capabilities in converting engines, for vehicles and for generating electric power, to be fueled by Bio-CNG. RGS is a Certified Workshop Installer for CNG conversion, awarded by the Directorate General of Land Transportation of the Republic of Indonesia. The workshop is located in the eastern part of Jakarta.

SERVICES OFFERED by RGS

- CNG conversion installers, kits, and parts supply
- CNG vehicles maintenance and repair
- CNG cylinders services and supply
- Diesel to Bio-CNG conversions for gensets and trucks

Process of RRS Bio-CNG commercialization for diesel fuel replacement



Toyota Dyna 130 PS

Mitsubishi 130 P

Bio-CNG fueled trucks converted by RGS

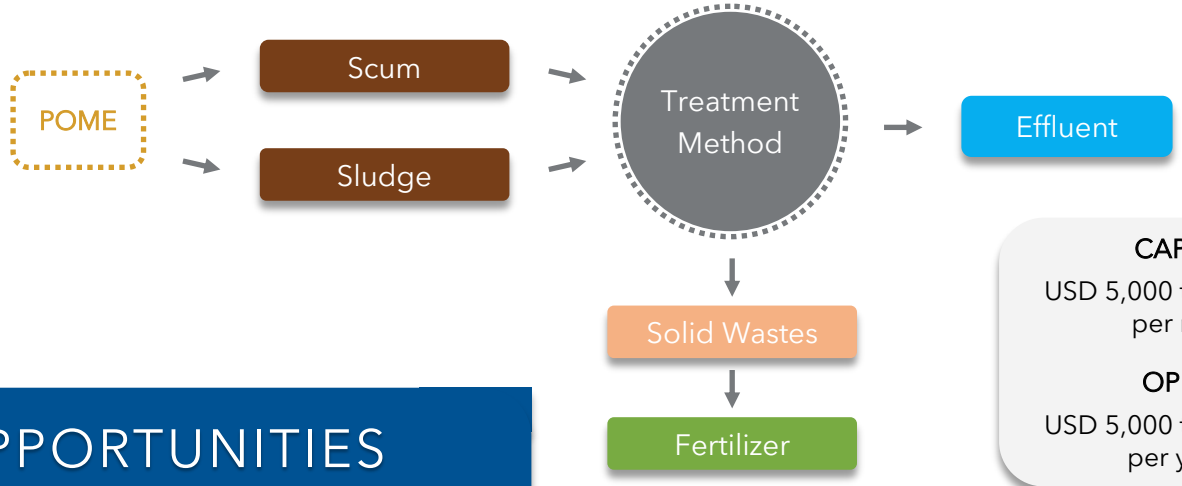
CONDITIONS FOR USE For Sale, For Service, Joint Venture

DEVELOPED IN Indonesia

PREFERRED REGION Indonesia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

SCUM and SLUDGE TREATMENT



CAPEX

USD 5,000 to 250,000 per mill

OPEX

USD 5,000 to 175,000 per year

OPPORTUNITIES

- Reducing GHG emissions
- Reducing the use of heavy machinery
- Dry solids can be used as compost, fertilizer, and soil conditioner
- Reducing waste pollutants in waterways

6,500 tons CO_{2eq}
per year

Potential GHG emissions reductions[11]

Raw POME is commonly treated using open lagoon systems, in which sludge and scum consistently and frequently accumulate, requiring regular desludging to maintain the pond's optimum condition. Generally, this cleaning is done yearly using mechanical excavation, which typically creates additional maintenance costs. Improvements to scum and sludge treatment can reduce the periodic maintenance costs caused by oil and sludge accumulation and create economic benefits, all while reducing GHG emissions by increasing efficiency of the wastewater treatment.

Images: (Left) Treated POME sludge at a dumping pond (Source–ResearchGate), (Right) Palm oil waste pond in Indonesia (Source–KPSR-biogas.com).

WIPO ID | 23715

Microbe-Lift

PT. Planetbiru Indonesia

Microbe-lift contains specialized microorganisms that are selected and designed specifically to speed up the biological degradation of problem compounds in wastewater systems. It was developed for more than four decades and has been applied in the Indonesian palm oil mill industry to kick-start pond restoration for over ten years. Microbe-lift uses a novel five-day, multistage fermentation process that gives a stable product with a self life of more than two years. The Microbe-lift technology reduces the need for excavators and new ponds while being a more environmentally friendly and sustainable solution to handle palm oil mill wastewater and sludge.

COLLABORATION TYPE For Sale

DEVELOPED IN United States

PREFERRED REGION Indonesia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

ADVANTAGES

- Reduces sludge formation and sludge handling costs
- Resistance to shock load
- Reduces BOD, COD, and TSS in effluent
- Improves the nitrification process
- Improves the settling quality

SERVICES OFFERED

by PT. Planetbiru Indonesia

- Consultancy
- Engineering

Image: Scum treatment process using the Microbe-Lift at an anaerobic pond (Source–Planetbiru).

WIPO ID | 23725

Geotube® Dewatering

TenCate Geosynthetics Asia Sdn. Bhd.

TenCate Geotube® dewatering containers offer a simple, cost-effective, and environmentally friendly solution for sludge dewatering. With this technology, specially engineered textiles that are fabricated into permeable containers are applied, which optimizes the solid retention, effluent discharge rate, and filtrate quality. TenCate Geotube® dewatering technology functions as follows:

1. *Containment*.
2. *Dewatering*: Allowing the water to drain through the membrane while solids are contained.
3. *Consolidation over extended time*: Allowing further drying of the biosolids inside the unit.

COLLABORATION TYPE For Sale

DEVELOPED IN Netherlands

PREFERRED REGION Global

READINESS LEVEL (TRL) Scaling Up (TRL 9)

Image: POME sludge captured by TenCate Geotube® Dewatering (Source–TenCate Geosynthetics).

ADVANTAGES

- One unit can produce 120 Metric Tons of dry solid
- Can reduce solid content from 3-8 percent to 1.5–3 percent
- Does not require additional land utilization
- Can produce a fertilizer acceptable for land application in two to three months

SERVICES OFFERED

by TenCate Geosynthetics

- Product supply
- Technical service

WIPO ID | 23709

C-tube Sludge Handling System

PT. Elmoz Geo Solusi

Elmoz's C-tube technology is a container made of geosynthetics designed for simplicity and low-cost application. Providing up to 90 percent sludge volume reduction, the C-tube is available in various sizes, depending on space requirement and sludge volume. The dewatering process for POME using the C-tube is as follows:

1. *Extraction (dredging or pump):* Removal of sludge from the waste pond.
2. *Dewatering*: Steady removal of water from the sludge in the technical textile tube.
3. *Disposal*: Sludge cake in a textile tube is removed and can be disposed of or used as fertilizer.

COLLABORATION TYPE For Sale

DEVELOPED IN Indonesia

PREFERRED REGION Indonesia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

Image: (Left) C-tube filling process and (right) dry solid captured (Source–PT. Elmoz Geo Solusi).

ADVANTAGES

- Reduction in COD and TSS
- Durable in the natural environment
- Easy handling and installation

SERVICES OFFERED

by PT. Elmoz Geo Solusi

- Consultancy
- Engineering
- Technical service

WIPO ID | 101324

Green Mark Dewatering Press System

Green Mark Projects Sdn. Bhd.

Green Mark Projects is a palm oil machinery manufacturer that specializes in waste treatment. Their Green Mark dewatering press is a continuous desludging system using a "squeezing" technology. The system can capture more than 99 percent of solids from POME, significantly reducing discharge of BOD and providing a product that is suitable for fertilizer use.

COLLABORATION TYPE For Sale, For Service

DEVELOPED IN Malaysia

PREFERRED REGION Indonesia and Malaysia

READINESS LEVEL (TRL) Scaling Up (TRL 9)

Image: Solid removal of dewatering system (Source–Green Mark Projects Sdn. Bhd.).

ADVANTAGES

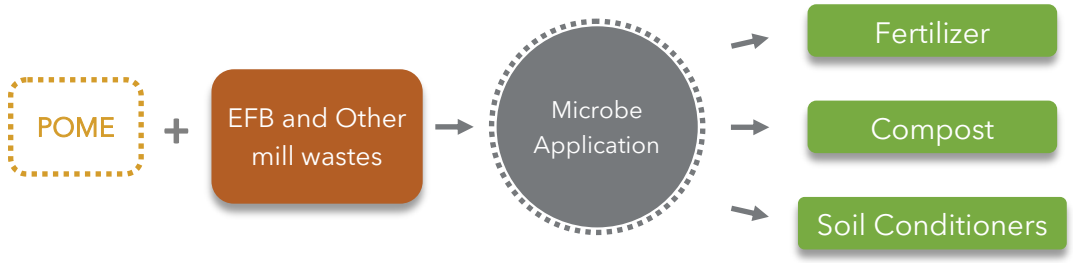
- High efficiency
- Eliminates the need for mechanical desludging
- Sludge cake can be used as a high NPK fertilizer
- Efficiently removes >80 percent COD
- Proven by ISCC and RSPO to effectively reduce GHG emissions

SERVICES OFFERED

by Green Mark Projects Sdn. Bhd.

- Product supply
- Turnkey
- Installation
- Technical consultancy and mill advisory services

COMPOST and FERTILIZER PRODUCTION



CAPEX

Up to USD 1.5 million
60 tons FFB/hour mill

OPEX

USD 100,000 to 135,000 per year

Decomposition of POME and the oil palm empty fruit bunch (EFB) can create value products in the form of organic compost and fertilizer. Composting is a biologically based process that stabilizes organic matter, and once formed, can be used to amend soils by increasing fertility as well as the soil's ability to retain moisture. Composting, where aerobic microorganisms decompose the substrate and the biodegradable organic compounds are broken down, is frequently used in the stabilization of organic palm oil waste. With the production of chemically stabilized composted material comes a portion of the remaining organic material that is converted into humic acid—a demonstrated amender of soil quality. The estimation of compost stability is essential for recycling organic waste in agricultural soils.[23]

Fertilizer is any material, natural or synthetic, that is applied to soils or to plant tissues for the purpose of supplying nutrients. POME can be dried and used as a fertilizer as it contains a high nutrient value, for example, in nitrogen.

The relationship between compost and fertilizer is as equally complementary as it is necessary for healthy plants, and in that way, the production of these products by a palm oil mill offers an opportunity to both mitigate GHG emissions as well as create additional value products and revenue streams.

88,000 tons CO_{2eq}
per year

Potential GHG emissions reductions of a 60 tons FFB per hour mill[18]

OPPORTUNITIES

- Reducing GHG emissions
- Generating new product and business stream
- Reducing the inorganic fertilizer consumption of oil palm plantations
- Reducing solid waste pollutants in local waterways

CHALLENGES

- Requires a large area for processing
- Organic compost and fertilizer market is not well developed

WIPO ID | 23727

EFB Aerobic Decomposition System

PT. Indmira

Indmira's EFB aerobic decomposition system is a technology that uses a mixture of POME and bacteria to decompose EFB. The aerobic decomposer speeds up the decomposition process without generating methane, reducing GHG emissions. This technology produces an organic fertilizer for soil restoration and that can be used on oil palm plantations to decrease the consumption of chemical fertilizers. The process is divided into four steps:

1. *Mix* liquid bacteria decomposer with POME in a pond.
2. *Arrange* EFB in the form of a pyramid.
3. *Spray* the EFB with the liquid mix of POME and bacteria twice a week.
4. *Monitor* the decomposition process twice a month.

COLLABORATION TYPE	For Sale, R & D Contract or Research Collaboration, For Service
PERFERRED REGION	Indonesia
PREFERRED REGION	Indonesia
READINESS LEVEL (TRL)	Scaling Up (TRL 9)

ADVANTAGES

- Reduces decomposition time of EFB
- Fertilizer produced is easily absorbed by plants

SERVICES OFFERED

by PT. Indmira

- Consultancy
- Technical service
- Supervision and monitoring
- R&D contract or research collaboration

Image: Decomposition of EPB waste (Source–Indmira).

WIPO ID | 23716

Composting and Plantation Bio-organic Solution

Vata VM Synergy (M) Sdn. Bhd.

Vata VM works with partners to provide enhanced nutrient bank capabilities and offer technology that transforms POME and EFB into nutrient management products through both anaerobic and aerobic processes. For composting, up to 50 percent of the POME and up to 100 percent of the EFB generated by a mill can be taken to a Vata VM compost plant. The compost and soil conditioners that are produced, when applied to the field with a Vata Nutrient Bank System, are proven to reduce the usage of chemical fertilizers by up to 40 percent, reducing potential groundwater contamination and restoring a soils organic carbon content without compromising the overall yield.

COLLABORATION TYPE	For Sale
DEVELOPED IN	Malaysia
PREFERRED REGION	Southeast Asia
READINESS LEVEL (TRL)	Scaling Up (TRL 9)

ADVANTAGES

- Compliance to ISPO, MSPO, and RSPO
- Compost plant can be integrated into an existing or new biogas facility
- 45 day composting period

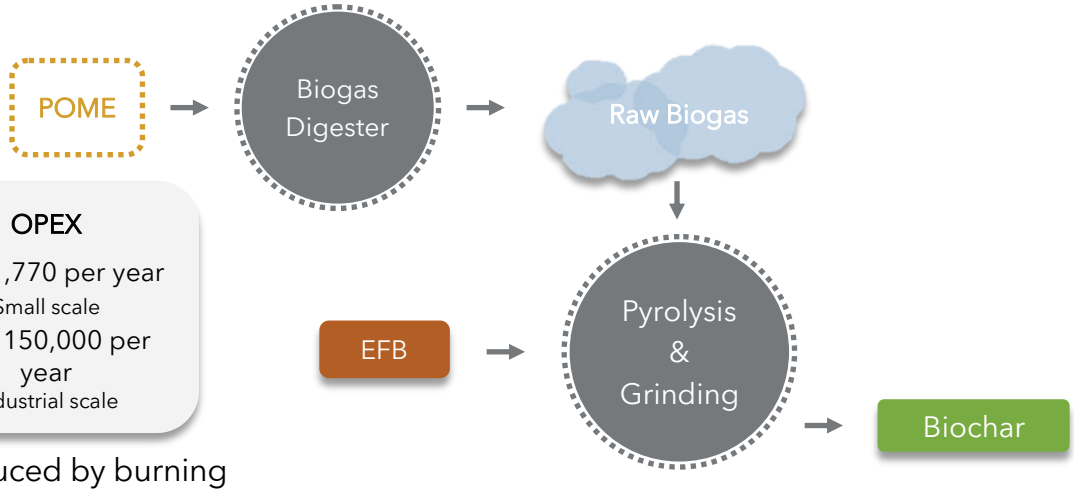
SERVICES OFFERED

by Vata VM Synergy

- Tailor-made composting systems
- Concession
- EPCC/ Consultation/Joint Venture
- Licensing
- R&D

Image: EFB Transferred to compost plant (Source–VATA VM).

BIOCHAR PRODUCTION



CAPEX	OPEX
USD 6,300 Small scale, 500 kg of EFB	USD 1,770 per year Small scale
USD 3.5 million 60 tons FFB/hour mill	USD 150,000 per year Industrial scale

Biochar, a charcoal produced by burning organic material in a low oxygen environment, is often used for soil remediation because of its ability to greatly benefit soils; from increasing water infiltration and nutrient retention capacity, to improving root development and enhancing biological activity and diversity.[24] Biochar use can aid in the mitigation of climate change impacts by increasing carbon stocks in soil, which in turn reduces GHG emissions.

Biogas produced by POME can be utilized as fuel and EFB can be used as the raw organic material, making biochar production a both environmentally and economically beneficial product related to the processing of POME.

OPPORTUNITIES

- Capturing carbon and utilizing carbon negative energy
- Reducing N_2O and methane soil emission
- Remediating soils on the oil plantation and critical lands
- Increasing water infiltration and nutrient retention capacity
- Increasing biological activity and diversity
- Increasing carbon stocks in soil

CHALLENGES

- Bio-char market is not well developed
- Bio-char application for soil remediation is relatively new

62,100 tons CO_{2eq}
per year

Potential GHG emissions reductions of a 60 tons FFB per hour mill[18,25]

WIPO ID | 23716

Biochar for Plantation Bio-organic Solution

Vata VM Synergy (M) Sdn. Bhd.

Vata VM works with partners to provide enhanced nutrient bank capabilities and offer technology that transforms POME and EFB into nutrient management products through both anaerobic and aerobic processes. Vata VM offers the addition of an integrated biochar production plant to their composting technology, which utilizes a process of pyrolysis, a chemical change made possible by thermal decomposition of materials at elevated temperatures, to produce biochar and a raw gas that can be further compressed to form bio-oil. In this way, the combination of the composting and biochar elements is proven to be both ecologically and economically beneficial.

COLLABORATION TYPE For Sale

DEVELOPED IN Malaysia

PREFERRED REGION Southeast Asia

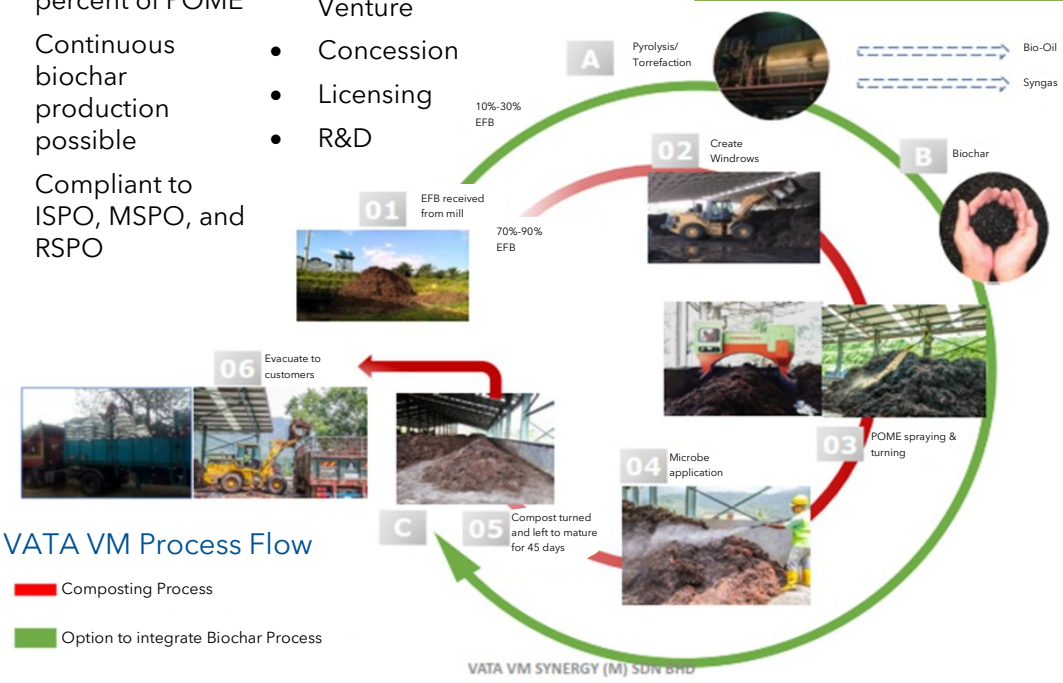
READINESS LEVEL (TRL) Scaling Up (TRL 9)

ADVANTAGES

- Can utilize 100 percent of EFB and up to 50 percent of POME
- Continuous biochar production possible
- Compliant to ISPO, MSPO, and RSPO

SERVICES OFFERED by Vata VM Synergy

- EPCC/Consultation/Joint Venture
- Concession
- Licensing
- R&D



WIPO ID | 101323

Biochar Production

Balai Penelitian Lingkungan Pertanian

Balai Penelitian Lingkungan Pertanian (Balingtan) is part of the Indonesian Center for Agricultural Land Resources Research and Development, umbrellaed under the Ministry of Agriculture, and develops technology for farmers that is easily adoptable and utilizes local materials. Currently patented and at their R&D center in Pati, Central Java is a protype of an integrated system for producing biochar from agricultural waste. The system involves a pyrolysis process that additionally utilizes condensation to produce a liquid smoke that can be used for producing antiseptic soaps, food preservatives, and cosmetics. Through increasing the temperature on the same process, activated carbon can also be produced.

CONDITIONS FOR USE R&D Contract, Research Collaboration, License

DEVELOPED IN Indonesia

PREFERRED REGION Indonesia

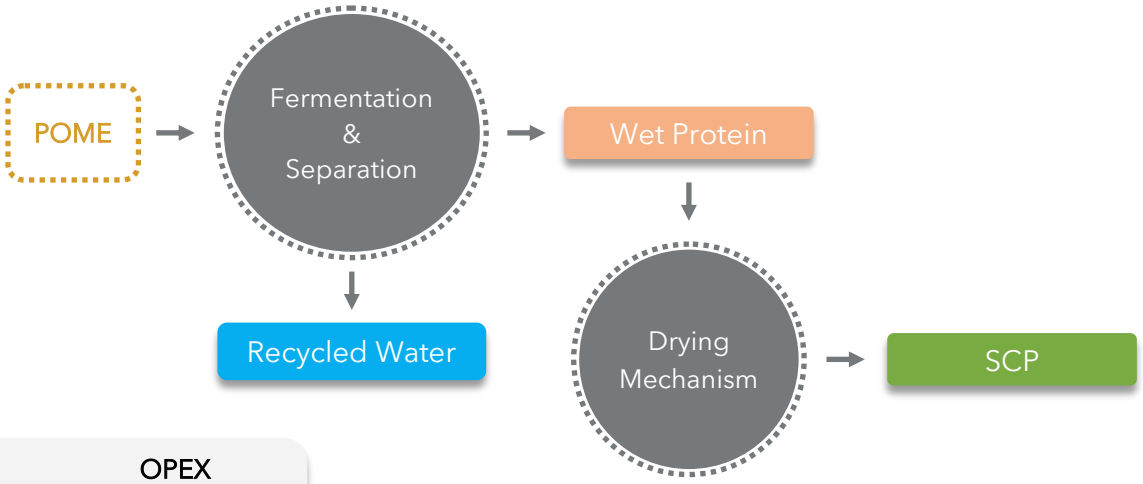
READINESS LEVEL (TRL) Early Commercial Demonstration/Adoption/ Dissemination (TRL 8)

SERVICES OFFERED by Balingtan

- Consultancy
- R&D collaboration

Image: Prototype of biodigester (upper) and biochar furnace (bottom) installation (Source–Balingtan).

ANIMAL FEED SUPPLEMENTS



CAPEX	OPEX
USD 2.5 million 45 tons FFB/hour mill	USD 575 per ton SCP

iCell Sustainable Nutrition Co., Ltd. (iCell) has an innovative technology solution for POME, dedicated to the integration of global environmental, biological, and nutritional resources, called Single-Cell Protein (SCP). Through producing SCP, iCell provides a dual, closed-loop solution for water and nutrients in the food industry chain. This technology takes the resource utilization of sludge and nutrient byproducts for value-added nutrient production as its core engagement to promote a low carbon footprint, resource recycling, and sustainable nutrition. The implementation of iCell technology leverages the utilization of POME to promote environmental sustainability, support the local Indonesia feed ingredient market, and help to reduce the import of feed ingredients for its shrimp, poultry, and cow feed producers.

OPPORTUNITIES

- Eliminating secondary pollution caused by POME sludge and other wastes
- Reducing GHG emissions
- Producing recyclable water for the conversion process

CHALLENGES

- Requires electrical energy
- Additional shipping and logistics for remote mills
- SCP must be sold as "functional ingredient" to achieve margins as means of market development with local feed customers
- Market is being developed and the product off-takers are still being identified

WIPO ID | 23738

Single-Cell Protein Production

iCell Sustainable Nutrition Co., Ltd.

iCell Sustainable Nutrition Co., Ltd. is a high-tech company with technology in environment, biology, and nutrition, and over 50 invention patents covering major economies of the world. By using its patented technology, iCell can utilize POME to produce a Single-Cell Protein (SCP) that can be used as animal feed to achieve a fully recycled economy of water and nutrients from the palm oil mill process that creates profitable environmental, social, and governance investments.

COLLABORATION TYPE License, Joint Venture

DEVELOPED IN United States

PREFERRED REGION Global

READINESS LEVEL (TRL) Scaling up (TRL 9)

ADVANTAGES

- Eliminates secondary pollution caused by sludge and other wastes
- Produces water for reuse for the SCP conversion process

SERVICES OFFERED

by iCell

- Licensing
- MiCell equipment sales/ leasing
- SCP buy-back for sale

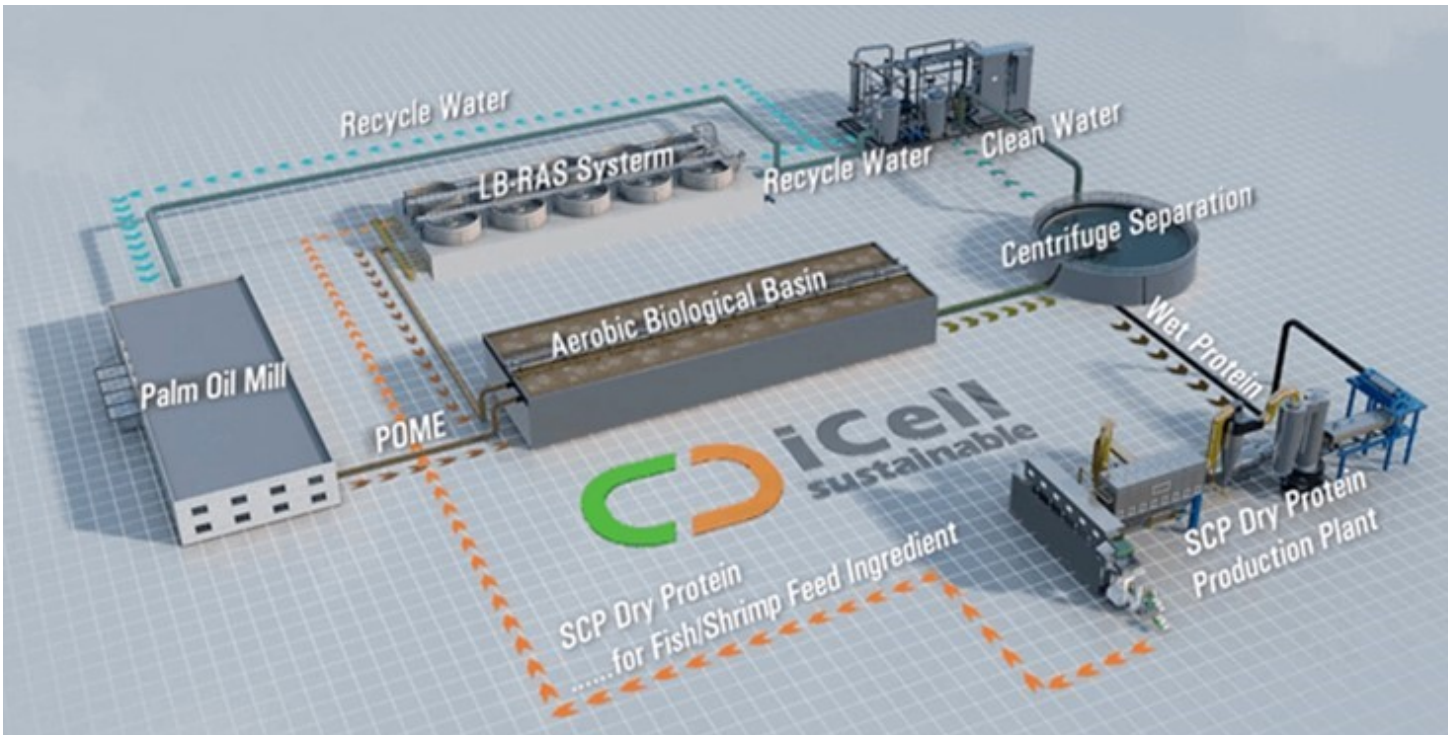
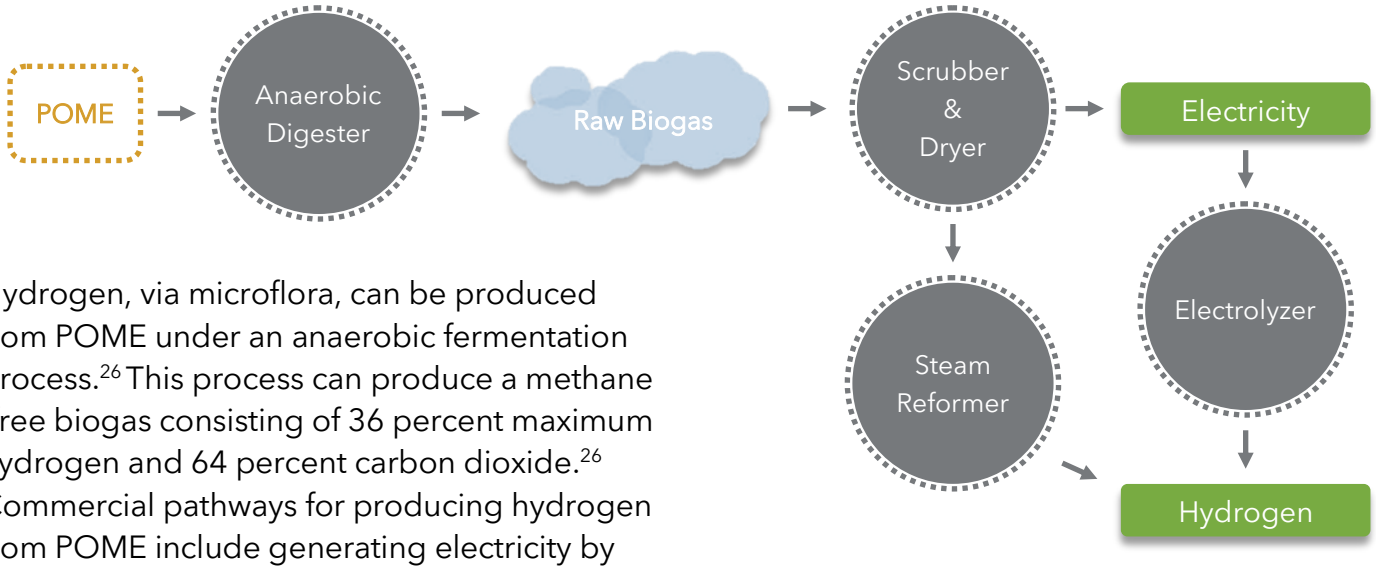


Image: iCell SCP process flow (Source—iCell).

GREEN HYDROGEN PROJECTS



Hydrogen, via microflora, can be produced from POME under an anaerobic fermentation process.[26] This process can produce a methane -free biogas consisting of 36 percent maximum hydrogen and 64 percent carbon dioxide.[26] Commercial pathways for producing hydrogen from POME include generating electricity by running an electrolyzer or via the addition of a stream reformer powered by the generated biogas.

Green hydrogen could provide energy systems with a long-term energy storage solution, capable of mitigating the variability of renewable resources, thus increasing the adoption pace of renewable energy.[27] Electrolyzers and fuel cell technologies are experiencing significant cost, efficiency and product quality improvements, with green hydrogen steadily closing the cost gap with fossil-fuel derived hydrogen in certain contexts and geographies.

OPPORTUNITIES

- Producing in-situ hydrogen to support the downstream processing in the palm oil industry
- Powering electrolyzers

CHALLENGES

- Further cost reductions are needed for green hydrogen to scale up
- Requires a hydrogen purification process up to 99.99 percent to be used in fuel cells[28]

WIPO ID | 23730

Hydrogen-to-Power Power Plants

HDF Energy

HDF Energy develops and operates high-capacity, large-scale hydrogen-to-power infrastructure to provide electricity from renewable energy sources that are combined with high power multi-megawatt fuel cells. By offering grid-friendly and stable decarbonized electricity solutions, HDF is accelerating the energy transition through making 100 percent renewable energy grids possible. HDF Energy has developed two models of turnkey hydrogen-to-power plants:

- *Renewstable® (Power-to-Power):* produces renewable electricity for grids and micro-grid operators and is composed of an intermittent renewable source as well as a long-term on-site hydrogen energy storage
- *Hypower® (Gas-to-Power):* produces electricity on demand from green hydrogen

COLLABORATION TYPE For Sale, Joint Venture

DEVELOPED IN France

READINESS LEVEL (TRL) Scaling up (TRL 9)

ADVANTAGES

- No toxic or chemical components released
- Reduces fossil fuel power generation

SERVICES OFFERED

by HDF Energy

- Market selection/sizing feasibility study/permitting
- SPV building and financing/equity investment
- Construction and commissioning
- O&M (20+ years)

Image: HDF Hypower power plant (Source–HDF).

REFERENCE MATERIALS

WIPO GREEN DATABASE USER GUIDE

Needs and technologies related to the treatment and valorization of POME in Indonesia that are not mentioned in the catalog can be uploaded to the WIPO GREEN Database to receive global visibility. Uploading and use of the database is free of charge.

Steps to upload technologies and/or needs:

1. Create an official WIPO account

- ⇒ Browse WIPO GREEN database
- ⇒ Click Become a user today
- ⇒ Proceed to create a WIPO account by completing the user information form
- ⇒ Click "Create an account"
- ⇒ Wait for an email confirmation to be sent to the email address you provided
- ⇒ Click on the link provided in the confirmation email in order to validate your WIPO account

2. Create an official WIPO GREEN profile

- ⇒ Once validated, login to your account on the WIPO GREEN database via the icon 
- ⇒ Create a WIPO GREEN profile by completing your profile information and selecting which WIPO GREEN service you are applying for
- ⇒ Once saved, the status of your request (s) will change to "Pending" and you will receive an email notification of your registration
- ⇒ A member of WIPO GREEN will verify your permissions within approximately two working days, and if granted, the permissions will change from "Pending" to "Granted"

3. Fill out and submit the technology/need form

- ⇒ Once your permissions are granted, navigate to the database tab and select "Submit Technology" or "Submit Need"
  - * If you wish to upload on behalf of another entity, use the contact information portion of the form and select "Yes" to expand the form
  - * If you wish to remain anonymous when uploading a need, you can use an anonymized name for the owner field
- ⇒ Complete the form and click save (optional: submissions can be added to the "POME Indonesia" collection)
- ⇒ You will then be presented with options to publish your article, click "Publish later" if you want to save it as a draft, or "Yes, publish" if you want to publish it right away. When published, you will receive a confirmation email
- ⇒ Your submission will appear on the WIPO GREEN database
  - * Your submission will automatically be matched against needs and technologies in the database upon submission. You will receive an email with potential matches and a "Saved search" will be created with email alert on by default
- ⇒ To manage your submission, navigate to the dashboard tab, and select "My submissions". To review your submissions statistics, select "My dashboard"
- ⇒ To take action on an existing submission (edit, suspend, delete, etc.), navigate to the action section of the bar to select the desired action

Please check on the WIPO GREEN database website for updates on the user guide. For questions, feedback, and technical inquiries, please contact the WIPO GREEN team at **wipo.green@wipo.int**

Needs of the Mills

The technology fields featured in this catalog were selected in response to the needs expressed by 14 palm oil mills in Indonesia during one-on-one interviews. The following are the summarized needs.

Technology field	Need
Biogas Utilization	POME to electricity project development.
	Technical assistance for preliminary assessments of biogas potential in the palm oil mills.
	Converting the existing POME treatment using open lagoon to biogas for flaring system.
H_2S Scrubber	Technology to reduce the H_2S level in the biogas before being utilized in the biogas engine.
Bio-CNG Project Development	Technical assistance in developing biogas/Bio-CNG plant and utilization.
	POME to biogas/Bio-CNG project development.
	Technical assistance to perform the Bio-CNG feasibility study.
Scum and Sludge Treatment	Scum removal treatment in acidification pond.
	Decreasing the BOD/COD level of final effluent.
	Anaerobic digester effluent separation technology to remove accumulated sludge in the sedimentation pond.
EFB Treatment	Integrated POME and biomass treatment system.
	EFB treatment to avoid emissions, accumulated waste, pests, and disease.
Investment and Carbon Market	Project developers/investors to process and to utilize POME and finding the buyers of the products such as compost, Bio-CNG, animal feed, etc.
	Carbon credit market/buyer from the biogas power plant system.
General	POME treatment technology options besides methane capture.
	POME treatment technology that is suitable in peatlands and economically profitable.
	POME treatment technology options that are economically profitable.

Detailed Needs of the Mills

The technology fields featured in this catalog were selected in response to the needs expressed by 14 palm oil mills in Indonesia during one-on-one interviews. The following are the summarized needs. The need and technology owners can be contacted through the WIPO GREEN Database.

Seeker	Location	Current Challenges	Need	Desired Outcomes
PT. Bangka Biogas Synergy	Bangka Island	Sediment accumulation in wastewater treatment ponds	Anaerobic digester effluent separation technology WIPO ID | 23663	• Separating sludge/cake from effluent water • Anaerobic digester effluent cake to be used for soil remediation and upgraded into fertilizer • Effluent to be used for land application or treated further for recycling within the processing plant
		The H_2S content after the installed biogas scrubber is around 500 ppm	Reduce the H_2S content before the biogas engine WIPO ID | 23664	• Technology, mechanism, or method that can reduce the level of hydrogen sulfide (H_2S) that will enter the biogas engine from 500 ppm to below 200 ppm
Palm Oil Mill 1	Muara Bungo	Conventional lagoons for POME treatment	Reducing GHG emission from existing POME treatment using open lagoons WIPO ID | 23723	• A joint venture scheme for the methane capture project or other technologies for the POME treatment • Generate additional revenue • Cooperation with investors is welcome
		Untreated EFB (140-180 tons per day) creates issues with pests and disease and emits GHG into the atmosphere	Treatment for EFB WIPO ID | 23733	• Treatment system for EFB (ex. composting to be used for soil remediation/organic fertilizer to promote sustainable farming) • Cooperation with investors is welcome assuming investor has strong buyers for product
Palm Oil Mill 2	Riau	Existing EFB treatment is left untreated	EFB Composting Plant WIPO ID | 86437	• Combine the EFB and POME treatment while adding value to the treated waste • Low investment cost and equipment supply is local • Preferably a build-to-own business model
Palm Oil Mill 3	Western Kalimantan	Conventional lagoons for POME treatment	Biogas for flaring system WIPO ID | 86438	• Plans to build biogas plants for flaring in 2021 at two mills • Company has a corporate target to reduce 10 percent of GHG emissions
Palm Oil Mill 4	Kalimantan	Barrier to implementing is budget	POME treatment technology WIPO ID | 86439	• Mill plans to utilize POME; hopes to develop the project with support from technology providers or investors • Interested in other technology options besides methane capture
Palm Oil Mill 5	Kalimantan	Conventional lagoons for POME treatment	Biogas power plant project developer WIPO ID | 86440	• Develop more biogas power plant project for implementing good sustainability practices in cooperation with project developer or investor for risk-sharing • Investors or project developers to develop a renewable energy project from POME in their mills

Seeker	Location	Current Challenges	Need	Desired Outcomes
Palm Oil Mill 6	Sumatera	Finding carbon credit market	Carbon credit market for a biogas power plant from POME with a capacity of 1.8 MWe WIPO ID | 86456	• Find a carbon credit buyer with competitive price
Palm Oil Mill 7	North Sumatera	Conventional lagoons for POME treatment to build in peatland	Economically profitable POME treatment technology for peatlands WIPO ID | 86457	• Cooperation with investors, technology providers or project developers on the project • Preferably can generate electricity to be sold to the PLN grid
Palm Oil Mill 8	Kalimantan	Decreasing the BOD and COD level of the final effluent before discharging it to a water body	Decreasing BOD level using cost-effective method WIPO ID | 86458	• More effective methods that support an environmentally friendly palm oil industry in decreasing BOD and COD level of final effluent • Additional treatment for effluent purification to recycle water through the boiler system
		Acidification and anaerobic ponds are experiencing scum build-up, which is requiring extra maintenance to control	Scum removal in pond WIPO ID | 86460	• More effective methods to remove the accumulated scum
Palm Oil Mill 9	Kalimantan	The shells and fibers are utilized for the biomass power plant while the POME is treated using open lagoons	Improved biogas and biomass treatment plants WIPO ID | 86459	• Create added value products from the mill's waste such as POME-to-electricity system combined with the biomass power plant
		Needs more information related to biogas in the Bio-CNG process and Bio-CNG utilization options	Bio-CNG feasibility study WIPO ID | 86466	• Find suitable technology for the Bio-CNG project development in their mills
Palm Oil Mill 10	Kalimantan	Conventional lagoons for POME treatment	Project developer of biogas/Bio-CNG plant WIPO ID | 86467	• Find suitable technology for the Bio-CNG project development in their mill • Cooperation with project developer and investor is preferable
Palm Oil Mill 11	Kalimantan	Needs technical support	Preliminary assessment of biogas potential WIPO ID | 86471	• Assessments of biogas potential and the technical and financial viability for their mills supported from grant/donor agency
	Jambi	Finding the best options of biogas and/or Bio-CNG plant utilization	Technology provider of POME to Bio-CNG plant and utilization WIPO ID | 86468	• Feasibility study • Cooperation with technology provider for the Bio-CNG project development in the mill

Seeker	Location	Current Challenges	Need	Desired Outcomes
Palm Oil Mill 12	Sumatera, Kalimantan, Sulawesi, and Papua	Currently using conventional open lagoons for POME treatment	Financially feasible and innovative POME treatment and utilization technology WIPO ID | 86469	• Produce valuable byproducts or generate energy from the POME treatment facility • Cooperation with technology provider or project developer is welcome
Palm Oil Mill 13	Sumatera	Existing EFB treatment is left untreated	Affordable EFB Treatment WIPO ID | 86470	• EFB treatment product that can be applied as soil remediation or upgraded to meet fertilizer's standard

Provider Contacts and Project References

Technology	Project References
CH_4 Generating Reactor by BPO www.bpo.rocketspark.co.nz	• PT. Gawi Makmur Kalimantan, Jorong Mill, 2x1.2 MWe, South Kalimantan, 2017 • PT. Gawi Makmur Kalimantan, Satui Mill, 2x1.2 MWe, South Kalimantan, 2016 • PT. Harapan Sawit Lestari (Cargill Tropical Palm), 2x625 kWe, West Kalimantan, 2015
Closed Lagoon Bioreactor by PT. Organics Bali www.organicsbali.com	• Sinarmas Group, Biogas for co-firing boiler, 3000 Nm^3 biogas/hour Central Kalimantan • Tedco Agri Makmur, Biogas from cassava mill effluent, 1000 Nm^3 biogas/h Bandar Lampung Sumatera • PT. CAM, Biogas from cassava mill effluent, 3000 Nm^3 biogas/h Kendari Southeast Sulawesi
Biological Scrubber by BPO www.bpo.rocketspark.co.nz	• PT. Gawi Makmur Kalimantan, Jorong Mill, South Kalimantan, 2017 • PT. Gawi Makmur Kalimantan, Satui Mill, South Kalimantan, 2016 • PT. Harapan Sawit Lestari (Cargill Tropical Palm), West Kalimantan, 2015
Biological Scrubber by PT. Elmoz Geo Solusi www.elmoz.co.id	• PT. Pasadena Biofuel Mandiri, Biogas power plant using Elmoz biogas biological scrubber, Riau, 2021 (Commissioning stage)
Biogas Upgrading Systems with Pressure Swing Adsorption by Carbotech Gas Systems Gas Systems www.ct-gs.com	• Natural Gas Well Upgrading Plant in Bambu Besar, Java
SEPURAN® Green by Evonik (SEA) Pte. Ltd. www.membrane-separation.com	• PT. Dharma Satya Nusantara, Bio-CNG plant, East Kalimantan, 2020
Biogas Power Plant Systems by PT. GREE Services Indonesia www.gree-energy.com	• Hamparan, Biogas from tapioca starch mill effluent, 3 MW – PPA to PLN, Central Lampung Sumatera
Biogas Power Plant Systems by PT. Elmoz Geo Solusi www.elmoz.co.id	• PT. Pasadena Biofuel Mandiri, Biogas methane capture plant, Riau, 2021 (Commissioning stage) • PT. Swadaya Mukti Prakarsa (First Resources Group), West Kalimantan, 2020 • PT. Sebaung Sawit Plantation, Digester system, North Kalimantan, 2019 • PT. Perdana Inti Sawit Perkasa, Biogas covered lagoon, Riau, 2019 • PT. Sarana Titian Permata, Digester system, Central Kalimantan, 2019 • PT. Mustika Sembuluh, Biogas power plant, Central Kalimantan, 2018 • PT. Perkebunan Milano Pinang Awan, Biogas power plant, North Sumatera, 2018 • PT. Mentaya Sawit Mas, Biogas project, Central Kalimantan, 2017

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